BBC Bitesize - Chemistry

Episode 3 – Atomic structure

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 atomic structure and the periodic table. In this episode we're going to look at subatomic particles, atomic structure and electronic configuration.

SUNAYANA: And we're looking inside at those protons, neutrons and electrons.

TULELA: We'll be comparing the size and the charge of each of those subatomic family members.

SUNAYANA: Looking at the difference between atomic number and atomic mass.

TULELA: And how the electrons in an atom are arranged according to their energy.

SUNAYANA: So in the previous episode we explored how the model of the atom developed over the past couple of centuries. And how our current model is one of a central nucleus where all the mass is concentrated, composed of positively charged protons and uncharged or neutral neutrons and that this is surrounded by negatively charged electrons orbiting in shells at specific distances.

TULELA: And we know that atoms are very, very, very tiny. But just how small are they? Time to call NNICK, our own chemistry know-it-all.

SUNAYANA: Kind of a speaking AI Chatbot.

TULELA: Hi, NNICK. Can you give us an idea of the size of an atom please?

NNICK: An atom is very small. The radius of an atom is about 0.1 nanometres. Or 1 x 10 to the -10 metres. Or nought point nought nought nought nought nought nought nought nought nought one metres.

The radius of a nucleus is about 1 x 10 to the -14 metres. Or nought point nought nought nought nought nought nought nought nought nought nought nought nought one metres.

For comparison, the thickness of a piece of paper is 1 x 10 to the -4 metres. Or nought point nought nought … well, you get the idea.

TULELA: Thanks NNICK, yes I think we do get the idea – those numbers are really small – an atom 0.1 nano metres! And the radius of a nucleus ten thousand times smaller still. How do you even begin to get your head around that, Sunayana?

SUNAYANA: You tell me!

TULELA: OK, so how about some analogies? Analogies are a good way of explaining sometimes complex ideas in science. So how do you picture an atom to give you a sense of what it's made of both and its size?

SUNAYANA: I like to think of an atom as a woodland. In the middle of the woodland is a small house where a family live. The house is like the nucleus of the atom and the family are the protons and neutrons inside. But far beyond the house are little fireflies darting about, and they're the electrons.

TULELA: That's a nice analogy.

SUNAYANA: What about you then?

TULELA: So I'm going to take you away from your woodland and move you into a football stadium. If we scale an atom up to the size of a football stadium and the electrons are tiny specks whizzing round the back row, then the nucleus would be on the centre spot and that would be the size of...

SUNAYANA: A football?

TULELA: No, a pea! This is where all the mass of the atom is concentrated. Most of the atom is empty.

SUNAYANA: And pretty much all its mass, the protons and neutrons, is in the nucleus of the atom with only a teeny tiny amount due to the electrons.

TULELA: Rather than calculating their actual mass in terms of kilograms, it's much easier to say that both protons and neutrons have an atomic mass unit – or amu – of one.

SUNAYANA: And an electron?

TULELA: We can just say it's very small as they hardly contribute anything to the overall mass of the atom.

TULELA: So that's the mass of each of those particles, what about electric charge? We've previously talks about protons having a positive charge, electrons a negative charge and neutrons being chargeless which we call neutral.

SUNAYANA: We can also say that every proton in the atom has a charge of plus one. Every electron has a charge of minus one and neutrons have a charge of zero. So that when you add up all the protons, neutrons and electrons and find that the overall electric charge of the atom is zero that must

mean that there are exactly the same number of protons as there are electrons as all those plus charges and minus charges cancel each other out.

TULELA: And conveniently, the number of protons that an element of a particular atom has is also how we define the atom's atomic number.

SUNAYANA: I also like to think of the atomic number as the address of an element – it tells you how many protons are in the nucleus and also its position in the periodic table. That's what makes an element unique. So, if two atoms have a different atomic number, then they have a different number of protons and are different elements.

TULELA: And as an atom has no overall charge, the number of protons is equal to the number of electrons in that atom.

SUNAYANA: For example sodium has 11 protons, and therefore 11 electrons – to ensure it has no overall charge and remains neutral. And so, its atomic number is 11. And that number is written at the bottom of the element's chemical symbol, in this case sodium is Na.

TULELA: What about those neutrons in the sodium nucleus? Where do they come in?

SUNAYANA: If we add together the number of protons and neutrons, we get the mass number. In the case of sodium there are 11 protons and 12 neutrons making a mass number of 23 – which we write at the top of the element's chemical symbol.

TULELA: So, atomic number – is just the number of protons which is like the address of the element. Mass number – the number of protons and neutrons added together which is all the stuff inside the house at that address. So all we need to know about what is in any atom is found by looking at the atomic number and mass number.

SUNAYANA: Spot on.

TULELA: So let's try this on a different element. What about krypton. Mass number 84, atomic number 36. So, dear podcast listening friend, how many protons, neutrons and electrons must krypton have? You can hit the pause button if you need to work it out or you've got 5 seconds before Sunayana attempts it….4…3…2…1…over to you!

SUNAYANA: So krypton has 36 protons because the atomic number is 36. 84 is the mass number which is the number of protons plus neutrons. And 84 minus 36 is the 48 so there must be 48 neutrons. And remember that in an atom, there are the same number of electrons as there are protons, so again, 36 – but they don't contribute to the mass number because they are so tiny!

TULELA: Like your fireflies buzzing around the woodland hut.

SUNAYANA: Let's keep with those tiny electrons whizzing around the nucleus. If you remember in the last episode, we said that they are orbiting the nucleus in shells at a particular distance.

TULELA: A bit like the planets orbiting the sun in our solar system.

SUNAYANA: Sure, well those shells can hold only a specific number of electrons. And the shells further out from the nucleus contain electrons with a higher energy. The shell nearest the nucleus can contain a maximum of 2 electrons and those electrons have the lowest energy. Then the next shell orbiting further away can contain a maximum of 8 higher energy electrons. And shell 3, further out still, also a maximum of 8 electrons with even higher energy.

TULELA: And in order to keep the atom stable, the electrons take up the lowest available energy shell first. We can use this now to fully describe an atom in terms of where the electrons are arranged according to which of the energy shells they're in.

SUNAYANA: So for example that sodium atom with 11 protons, and 12 neutrons – it must also have 11 electrons to ensure it's neutral, and those electrons are arranged across three shells with 2 in the lowest energy shall nearest to the nucleus, 8 in the next shell and one remaining in the third shell with the highest energy.

TULELA: And this can be shown on a diagram, with circles around the nucleus to represent the shells and crosses on the shell to represent each electron.

SUNAYANA: Or simply stated that sodium has an electron arrangement of 2,8,1. After the podcast have a go at drawing the electron arrangement of fluorine which has an atomic number of 9. And you can find the diagram to compare your answer to as well as other examples on Bitesize on the web.

SUNAYANA: Time for a quick recap, Tulela?

TULELA: Yep, start us off.

SUNAYANA: Atoms are tiny. They have a central nucleus of protons and neutrons, around which are orbiting electrons.

TULELA: Protons and neutrons have an atomic mass of one. Electrons are very small in comparison.

SUNAYANA: Protons have a charge of +1. Electrons have a charge of -1 and neutrons have zero charge.

TULELA: The number of protons in an atom is called the atomic number. The number of protons is equal to the number of electrons and this is why atoms have no overall charge.

SUNAYANA: Adding the number of protons and neutrons together gives us the mass number of the element.

TULELA: And the electrons are arranged in energy shells in a specific order, occupying the lowest available shell.

TULELA: In the next episode, we'll be looking at isotopes, how the same element can have a different number of neutrons and therefore mass number.

SUNAYANA: I'm Dr Sunayana Bhargava.

TULELA: And I'm Tulela Pea.

SUNAYANA: And this is Bitesize Chemistry. To hear more, search Bitesize Chemistry on BBC Sounds.

TULELA: Say bye Sunayana!

SUNAYANA: Bye Sunayana!

TULELA: Bye everyone.