BBC Bitesize - Chemistry

Episode 7 – States of matter

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.

SUNAYANA: This is the seventh episode of an eight-part series on bonding, structure and properties. In this episode, we're going to look at states of matter and changing states.

TULELA: Solids (the most dense state), liquids and gases (the least dense).

SUNAYANA: And looking at what's going on according to the particle model. And we'll be looking at how adding or taking energy away from a substance can convert it from one physical state to another.

TULELA: And dear podcast listening friends, grab some pen and paper and take some notes.

SUNAYANA: Look around you as you listen to this episode and everything you see, no matter where you are, is almost certainly in one of the three states of matter.

TULELA: Solid, liquid or gas.

SUNAYANA: In the Bitesize podcast studio, I can see solids which are tables, chairs, people and tea cups. But in the tea cup I can see a liquid, tea… and because the tea is still hot, I can see a gas, a trail of steam floating off into the air.

TULELA: We are so used to these three states of matter in our everyday lives, but what is going on in terms of chemistry and on a particle level – that's what we'll be looking after NNICK, our Bitesize binary-banter-bot gives us a quick summary of model of matter. Hi NNICK. Can you tell us about the three states of matter accordingly to the particle model?

NNICK*:* People say to me, "NNICK, what's the matter?" "Oh," I reply, "the matter is a collection of atoms, and it's in one of three states; solid, liquid or gas." If you heat up a solid, it melts to become a liquid. If you heat up a liquid, it boils to become a gas. Conversely, if you cool down a gas, it condenses to become a liquid. If you cool down a liquid, it freezes to become a solid. How much energy it takes to change the state of a substance depends on the strength of the forces between its particles; the stronger the forces, the higher the melting and boiling points.

SONG

Heat up a solid
It melts to become a liquid
Which can flow, but can't be compressed

Heat up a liquid
It boils to become a gas
Which can be compressed
Because each of its particles is further from the rest

Cool down a gas
It condenses to become a liquid
And now its particles have much less space

Cool down a liquid
It freezes to become a solid
Which can't flow in its space
Because each of its particles is fixed in its place

SUNAYANA: Thanks NNICK, so from what NNICK has summarised, we can visualise each individual molecule or ion or atom in the particle model as a solid sphere – like a snooker ball. And the properties of each state of matter depends on the forces between the particles.

TULELA: If we look at each in turn. In a solid, those particles are held together in a fixed rigid lattice by strong forces and each individual particle is in a low energy state.

SUNAYANA: In a snooker game, this is like the start of a game when all the red balls are tightly packed together within a triangular rack or frame with each ball touching its neighbours – no ball can swap position within the frame.

TULELA: Solids have a fixed shape and fixed volume and cannot be compressed because in this model, there is no space for the particles to move into. Let’s add some energy to the solid.

SUNAYANA: When we heat the solid, the particles gain more energy. They vibrate more and this weakens the bonds holding them together.

TULELA: In the snooker game, we’ve removed the triangular frame holding the balls rigid so that now the balls can jiggle around more and although they are free to roll around and move past each other, they do tend to stick together and remain in contact with each other.

SUNAYANA: The solid has become a liquid and the temperature at which this occurs is the melting point. Liquids don’t keep a definite shape, the particles are not in a fixed position but rather randomly arranged and they have greater energy than when they were in a solid.

TULELA: But like a solid, liquids still keep their same volume because, again, the particles are so close together that they have no space to move into. It’s like the tea in my cup, liquids flow to fill the bottom of a container. The reverse of melting, that is if we went from a liquid to a solid, is freezing.

SUNAYANA: OK. More heat, more energy. As we continue to heat our liquid, the particles move faster with more energy, weakening and breaking the bonds that hold them together, eventually overcoming the force of attraction holding them together. They are free to move, they spread out with higher energy. The liquid becomes a gas. And the temperature at which this happens is called the boiling point of the substance.

TULELA: Back on the snooker table, we can imagine this as the balls spreading out across the entire surface of the snooker table, bouncing off the cushions and each other with high speed.

SUNAYANA: Gas particles are spread out, move quickly in all directions at random and have the highest energy compared to particles in the solid and liquid states. Gases don't keep a definite shape or volume and spread out to fill the entire space available to them, and so a gas can be compressed because the particle do have space to move into.

TULELA: A liquid becoming a gas happens at the boiling point of that liquid, but you may have heard the term evaporation which is closely connected. Both describe a liquid turning into a gas, but evaporation only happens at the surface of the liquid and can happen at any temperature.

SUNAYANA: Like the steam escaping from the top of my cup of tea.

TULELA: Whereas boiling only happens at the specific boiling point and happens throughout the entire liquid.

SUNAYANA: And the reverse of boiling – that is going back from a gas to a liquid – is called condensing.

TULELA: So quick summary, the melting point is the point at which a solid turns into a liquid if we're heating it or a liquid becomes solid if we're cooling it. And boiling point where a liquid changes into a gas if we're heating it or a gas becomes a liquid if cooling.

SUNAYANA: And these points both relate directly to how strong the forces of attraction are between the particles. The stronger the force, the more energy is needed to break those bonds and so the higher the melting and boiling points are.

TULELA: If you remember from previous episodes, we saw in ionic compounds – like our friend sodium chloride - the strength of the bonds inside the ionic compound was comparatively higher than the forces between simple covalent compounds – like H_2O water. And this is the reason why we found that ionic compounds have much higher melting and boiling points than simple covalent substances.

SUNAYANA: How about a states of matter example, Tulela?

TULELA: Why not indeed.

SUNAYANA: You might want to grab a pen and paper so you can write some of these numbers down. OK, so we can use the information about a substance's melting and boiling point to predict what state it will be in at a particular temperature. If the temperature is lower than the melting point, it will be a solid. If the temperature is higher than boiling point, it will be a gas. And if the temperature is between the two, then it will be a liquid.

So I've got two substances here. Substance A has a melting point of minus 220 degrees Celsius and a boiling point of minus 183 degrees Celsius. And substance B has a melting point 800 degrees Celsius and a boiling point of 1400 degrees Celsius. What state of matter will each be at 1000 degrees Celsius? You can play along at home and no need to heat or cool anything with that information.

TULELA: OK – first one, substance A – melting point minus 220 degrees Celsius and boiling point minus 183 degrees Celsius. So both very low and much lower than the 1000 degrees Celsius. If we look at the boiling point, it's lower than the temperature given so it must be a gas.

SUNAYANA: Correct.

TULELA: And substance B melting point 800 degrees Celsius, boiling point 1400 degrees Celsius and the temperature of 1000 degrees Celsius is between the two, so it must be a liquid.

SUNAYANA: Spot on.

TULELA: Summary time, Sunayana.

SUNAYANA: The three states of matter are solid, liquid and gas. Melting and freezing take place at the melting point, boiling and condensing take place at the boiling point.

TULELA: The amount of energy needed to change state from solid to liquid and from liquid to gas depends on the strength of the forces between the particles of the substance. The stronger the forces between the particles, the higher the melting point and boiling point of the substance and vice versa.

SUNAYANA: Solids have fixed shapes and cannot be compressed as the particles are not free to move.

TULELA: In liquids and gases the particles are free to move. A liquid takes the shape of its container and also cannot be compressed. And gases completely fill their container and can be compressed. And we can use information about a substances melting and boiling point to predict its state at any temperature.

SUNAYANA: As always there's loads more guides to GCSE chemistry topics on the BBC Bitesize webpages.

TULELA: And you can listen on BBC Sounds to many other episodes in this or other podcast series of Bitesize chemistry with me, Tulela .

SUNAYANA: And me, Sunayana. Your turn, Tulela. [SOUND OF SNOOKER BALLS]

SUNAYANA: Good shot!