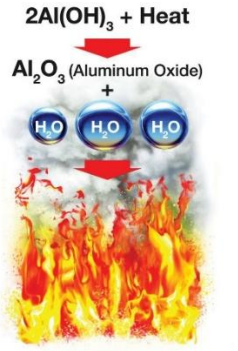
Cable insulation

Electrical cables carrying large amounts of electricity can potentially overheat and catch on fire. To avoid this, they fill the insulation (outer layer) with a flame retardant – a chemical that helps to prevent overheating and fires starting.

A common flame retardant is **aluminium hydroxide**, $Al(OH)_3$, is a white solid that is begins to react at 150 ℃.

Aluminium hydroxide in cables

Aluminium hydroxide preventing fires



Equations

aluminium hydroxide → aluminium oxide + water

$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(l)$

Observations and Tests

- If the aluminium hydroxide is left at room temperature nothing happens. A reaction only happens ***if it is heated above 150°C.***
- When the cable heated up and the reaction began, there was no visible sign of reaction.
- After the reaction, the cables were allowed to cool. If the plastic insulation was carefully removed from a portion of the cable, blue cobalt chloride paper turned pink when rubbed over the cable.
- The cables were visibly coated with a fine white solid.

This is a (thermal) decomposition reaction because one reactant (aluminium hydroxide) breaks down or decomposes when heated into a larger number of products (here 1 x aluminium oxide and 3 x water). It matches the general word equation on the resource sheet: metal hydroxide → metal oxide + water.

aluminium hydroxide → aluminium oxide + water

$$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(l)$$

Aluminium hydroxide, the reactant, is a white solid; most ionic compounds are white with the exception of some compounds containing lead or a transition metal such as copper, iron or silver. There is no visible sign of a reaction as the (ionic) product, aluminium oxide, is also a white solid. Water, the other product, would be formed as steam but once condensed it is a colourless liquid that would turn blue cobalt chloride paper pink, identifying water as a product.

aluminium hydroxide → aluminium oxide + water

$$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(l)$$

Conservation of mass means that the mass of the reactants equals the mass of the products; no atoms are lost or gained in the reaction as the atoms just rearrange into new combinations. The aluminium of the aluminium hydroxide ends up as the aluminium of the aluminium oxide. The hydroxide group provides hydrogen atoms for the water formed and oxygen atoms end up either in the aluminium oxide or as part of the water. In the reactants there are 2 x Al, 6 x O and 6 x H atoms which is the same as in the products 2 x Al in Al_2O_3 , 6 x H in 3 molecules of H_2O, and 6 x O atoms, 3 in Al_2O_3 and 3 in the 3 molecules of H_2O. If you could measure the mass of the aluminium oxide and water produced it would be the same as the mass of original aluminium hydroxide.

The aluminium hydroxide is added to cables early on in their manufacture. It is added to the layer of plastic insulating material, and then this layer is heated and moulded to fit around the wires.

Cable material		Moulding temperature (°C)
PVC		180
Polyethylene		200
Nylon		80

Explain why aluminium hydroxide is suitable for use in nylon cables but not PVC and polyethylene cables.

Include in your answer:

- How aluminium hydroxide prevents fires starting.
- The implications of not incorporating enough aluminium hydroxide
- How the ability of aluminium hydroxide to stop fires could be impacted during moulding of the cables.

The fire retardant ability relies on the aluminium hydroxide surrounding the electrical cables; it decomposes at temperatures over 150°C to prevent overheating and fires starting. If there is insufficient aluminium hydroxide then it may be that not enough water is produced in the decomposition reaction to extinguish a fire.

Since both PVC and polyethylene cables have a moulding temperature above 150°C they are both unsuitable as the aluminium hydroxide would decompose to aluminium oxide during the manufacture of the cables (and therefore have no fire retardant properties).