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A Level Physics B (Advancing Physics)

H557/02 Scientific literacy in physics

Advance Notice

Practice paper 1

Time allowed: 2 hours 15 minutes

To be read on receipt

To prepare candidates for the Practice paper.

NOTES FOR GUIDANCE (CANDIDATES)

1. This leaflet contains an article which is needed in preparation for a section in the externally assessed examination H557/02 Scientific literacy in physics.

2. You will need to read the article carefully and also have covered the learning outcomes for A Level in Physics B (Advancing Physics). The examination paper will contain questions on the article. You will be expected to apply your knowledge and understanding of the work covered in A Level in Physics B (Advancing Physics) to answer this question. There are 20–25 marks available on the question paper for this question.

3. You can seek advice from your teacher about the content of the article and you can discuss it with others in your class. You may also investigate the topic yourself using any resources available to you.

4. You will not be able to bring your copy of the article, or other materials, into the examination. The examination paper will contain a fresh copy of the article as an insert.

5. You will not have time to read this article for the first time in the examination if you are to complete the examination paper within the specified time. However, you should refer to the article when answering the questions.

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The Physics of Cooking

Science in the kitchen

The kitchen offers many examples of physics, but a real understanding of the way in which physics is applied in the kitchen depends on a basic understanding of the nature of cooking.

The chemistry of cooking can be very complex, but one simple idea is sufficient to explain much of it. The biological molecules found in meat, or in uncooked vegetables, are long-chain polymer molecules, which are often difficult or impossible for our digestive systems to break down. The cooking process splits up these polymer chains into forms that our digestive systems can deal with. At the same time, some of the small molecules produced carry the mouth-watering sensations of flavour to the flavour receptors in our noses. The important applications of physics in the kitchen – particularly heat transfer – are ways in which we can control and accelerate these processes.

The Chemistry of Cooking

The chemical and biological processes in many living things, such as mammals and birds, generally take place best at temperatures of about 37°C (310 K), the temperature of our bodies. Although particularly hardy micro-organisms can survive in temperatures as low as 0 °C and as high as 115 °C, most living tissues are damaged at temperatures higher than about 40 °C. This is due to changes taking place in the protein molecules of the tissues.

The protein collagen is found in animal connective tissue, and it makes meat 'tough'. This is because collagen consists of a triple helix of long-chain molecules, tightly wound together. At temperatures above about 70°C the indigestible collagen molecules begin to disentangle to form gelatin, as shown in Fig. 1. The term 'tough' is used rather differently in describing strong materials such as metals.

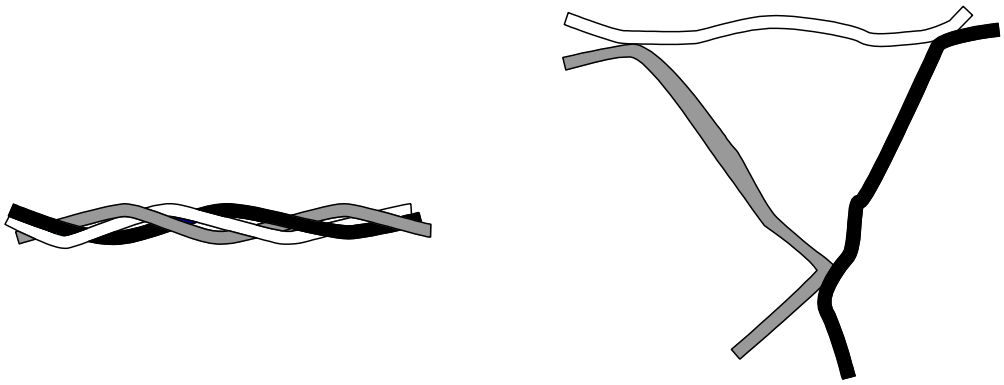

Fig. 1

Gelatin has fewer bonds between chains, which is why long, slow cooking makes meat tender and often causes it to it fall apart. For the same reason, gelatin is easily digested. Gelatin is used in jelly, where it forms open networks that hold water in large quantities. The presence of molecular pathways throughout the jelly means that it behaves as a solid, although heating to 30 °C weakens the links between the polymer chains, allowing the jelly to 'melt.'

More interesting processes take place at higher temperatures. In particular, chain-breaking reactions between proteins and carbohydrates occur at about 140°C to produce a number of smaller molecules. These reactions are called Maillard reactions. The activation energy for a Maillard reaction – typically about 70 kJ mol^{-1} (about 1.2×10^{-19} J or 0.7 eV per molecule) - is two

or three times higher than the energy needed to disentangle protein chains, as stronger bonds need to be broken. Some of these small molecules are responsible for the characteristic appetising smell of cooking, while others produce the brown colours of cooked food.

To speed up cooking, you can heat the food at higher temperatures. The rate of a chemical reaction with activation energy *E* depends on the Boltzmann factor $f_B = e^{-\frac{E}{kT}}$. At typical cooking temperatures, every 10 K rise in temperature *T* roughly doubles the rate of the reactions concerned, and cooks the food faster. On the negative side, at higher temperatures, Maillard reactions produce bitter flavours as well as chemicals which it has been suggested could contribute to cancer of the digestive system. Furthermore, if the temperature of the food is raised too much, the molecules are broken down completely to leave brown residues of carbon. This is caramelisation, which is fine in crème caramel or in gravy browning, but is not usually wanted when cooking – just think of badly-barbecued sausages, raw in the middle and thick sooty carbon on the outside!

Kitchen Thermometers

Whether food is cooked or not depends on its temperature, so a thermometer is an obvious scientific instrument to bring to the kitchen. If nothing else, you can check the temperature settings of your oven, to see how accurate they are! Liquid-in-glass jam thermometers have been common for many years, but electronic thermometers are now readily available. These allow the temperature at the very centre of the food, such as a piece of meat, to be measured during cooking. The sensor of the electronic thermometer, either a thermistor or a thermocouple, is stuck deep into the piece of meat and a cable connects it to an electronic circuit and digital display unit.

Thanks to Dr Peter Barham, University of Bristol, for permission to use material from his book *The Science of Cooking* (Springer-Verlag 2001)

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