



- 3 Convert this energy into joules.

This gives you the energy released when two deuterium nuclei fuse. The next steps take you through the calculation of the total energy released if all the deuterium in the kettle water were to fuse to make helium-3. The ratio of deuterium atoms to hydrogen in water is roughly 1 to 7000.

- 4 What is the mass of 1 mole of water ( $H = 1 \text{ u}$ ;  $O = 16 \text{ u}$  roughly)?

- 5 How many moles of water are contained in the litre?

- 6 How many molecules of water ( $H_2O$ ) are in the kettle?

- 7 How many molecules of deuterium oxide ( $D_2O$ ) are in the kettle?

- 8 Each heavy water molecule has two atoms of deuterium; what total energy is released if all the deuterium in the kettle is converted to helium-3?

Now to put this number in a new perspective. It requires 4200 J to increase the temperature of 1kg of water by 1K.

- 9 How many litres of water could be heated through 100 K by the fusion energy you calculated in question 8?

## Hints

- 1 It is important to consider the atomic electrons in this equation. You begin with two, one for each hydrogen. How many electrons does an un-ionised atom of deuterium have? So what must one of the emitted particles be? This should lead you to the other particle.
- 2 The conversions you need are near the data table in the question.
- 4 The formula of water shows that there are two hydrogen atoms and one oxygen for each water molecule.
- 5 1 litre of water has a mass of 1 kg.
- 6 1 mole contains  $6 \times 10^{23}$  molecules of water.

## Practical advice

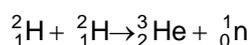
These questions can be modified in many ways, not least by changing the homely example of a kettle to perhaps a bath full of water or even to Lake Windermere or the local reservoir.

## Social and human context

The 6000 litres of heated water may not seem so significant until you realise that this has come from the fusion of deuterium which had an original volume of  $0.15 \text{ cm}^3$ .

## Answers and worked solutions

1.



2.  $\Delta m = (3.016\,030 \text{ u} + 1.008\,665 \text{ u}) - 2 \times 2.014\,102 \text{ u} = -0.0035 \text{ u}$

3.  $0.003509 \text{ u} \times 931 \times 10^6 \text{ eV u}^{-1} \times 1.6 \times 10^{-19} \text{ J eV}^{-1} = 5.23 \times 10^{-13} \text{ J}$

4. 18 g

5. 1 litre of water has a mass of 1 kg.

$$\text{number of moles} = 1000 \text{ g} / 18 \text{ gmol}^{-1} = 56 \text{ mol}$$

6.  $56 \text{ mol} \times 6.02 \times 10^{23} \text{ mol}^{-1} = 3 \times 10^{25}$

7.  $(3.4 \times 10^{25}) / 7000 = 4.9 \times 10^{21}$

8. energy released =  $4.9 \times 10^{21} \times (5.23 \times 10^{-13} \text{ J}) = 2.49 \times 10^9 \text{ J}$

9.  $(2.49 \times 10^9 \text{ J}) / (4200 \text{ J kg}^{-1}\text{K}^{-1} \times 100\text{K}) = 6000 \text{ kg} = 6000 \text{ litres}$

## External reference

This activity is taken from Advancing Physics chapter 18, 260S