Teacher notes
Topic B

Hydrogen in the Sun and escape speed

We know that $\frac{1}{2}mc^2 = \frac{3}{2}kT$ and so the average speed of hydrogen atoms at the surface of the Sun is

$$c = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 5800}{1.67 \times 10^{-27}}} = 1.2 \times 10^4 \text{ m s}^{-1}$$

The escape speed from the surface of the Sun is

$$v_{\text{esc}} = \sqrt{\frac{2GM}{R}} = \sqrt{\frac{2 \times 6.67 \times 10^{-11} \times 2.0 \times 10^{30}}{7.0 \times 10^8}} = 6.2 \times 10^5 \text{ m s}^{-1}$$

Since $c << v_{\text{esc}}$ no hydrogen atoms can escape from the Sun. Elements heavier than hydrogen have even lower speeds so they cannot escape either.

Yet we know that there are streams of particles that do escape from the Sun and make it to Earth. How is this possible?

The upper layers of the Sun's atmosphere (the corona) has a temperature that is in the millions of degrees K. Can particles escape from the corona? The average speed of hydrogen atoms in the corona at a temperature of 4×10^6 K is

$$c = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 4 \times 10^6}{1.67 \times 10^{-27}}} = 3.1 \times 10^5 \text{ m s}^{-1}$$

This is still less than the escape speed, about half the escape speed. But remember that we are only calculating the average speed. Some molecules (about 0.5% in fact) will have a speed higher than 2*c* and they will be able to escape.