

Force	Electromagnetic	Strong nuclear	Weak nuclear
Acts on	Protons only	Protons and neutrons	Protons and neutrons
Nature	Repulsive	Attractive (mainly)	Attractive/repulsive
Range	Infinite	Short ( $10^{-15}$ m)	Short ( $10^{-17}$ m)
Relative strength	$\frac{1}{137}$	1	$10^{-6}$

Table 1.2 Forces operating in the nucleus.

There is one other force acting in the nucleus apart from the electrical and strong nuclear forces. This is the weak nuclear force, a force that is responsible for the decay of a neutron into a proton. The details of this decay (beta decay) will be examined in the next chapter. The forces acting in the nucleus are summarized in Table 1.2.

(Since the masses of subatomic particles are so small, the gravitational force is irrelevantly small compared with the other three forces.)

### Questions

- The radius of an atomic nucleus is given by the expression
 
$$R = 1.2 \times A^{1/3} \times 10^{-15} \text{ m}$$
 where  $A$  is the mass number of the nucleus.
  - Use this expression to find the density of a nucleus of iron ( ${}_{26}^{56}\text{Fe}$ ) in  $\text{kg m}^{-3}$ .
  - How does this density compare with the normal density of iron?
  - If a star with a mass equal to 1.4 times the mass of our sun (solar mass =  $2.0 \times 10^{30}$  kg) were to have this density, what should its radius be? (Such stars are formed in the end stage of the evolution of normal stars and are called neutron stars.)
- Use the expression for the radius of a nucleus to show that all nuclei have the same density.
- Describe carefully how the Geiger–Marsden–Rutherford experiment gave rise to the Rutherford model of the atom. Why is the experiment you just described inconsistent with Thomson’s model of the atom?
- Explain why the dark lines of an absorption spectrum have the same wavelengths as the bright lines of an emission spectrum for the same element.
- What is an isotope? How do we know that isotopes exist?
- Find the number of neutrons in these nuclei:  ${}^1_1\text{H}$ ;  ${}^4_2\text{He}$ ;  ${}^{40}_{20}\text{Ca}$ ;  ${}^{210}_{82}\text{Pb}$ .
- What is the electric charge of the nucleus  ${}^3_2\text{He}$ ?
- What is meant by the statement that the energy of atoms is discrete? What evidence is there for this discreteness?
- What do you understand by the statement that the strong nuclear force has a short range?
- What is the dominant force between two protons separated by a distance of:
  - $1.0 \times 10^{-15}$  m;
  - $1.0 \times 10^{-14}$  m?
- Explain why a nucleon feels the strong force from roughly the *same number* of other nucleons, irrespective of the size of the nucleus.

### HL only

- Compare the gravitational force between two electrons a distance of  $10^{-10}$  m apart with the electrical force between them when at the same separation.