9 **(a)** Fig. 9.1 shows the visible part of the emission spectrum from hydrogen gas in a laboratory on the Earth. The numbers indicate the wavelength, in nm, represented by each line.

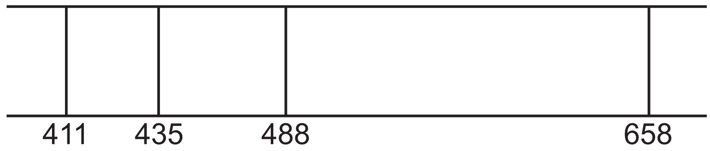

Fig. 9.1

(i) Explain how the emission spectrum provides evidence for the existence of discrete energy levels for the electron in a hydrogen atom.

....

....

....

.... [3]

(ii) Fig. 9.2 shows five of the energy levels in the hydrogen atom. The wavelengths of radiation shown in Fig. 9.1 relate to transitions to the −3.400 eV level in Fig. 9.2.

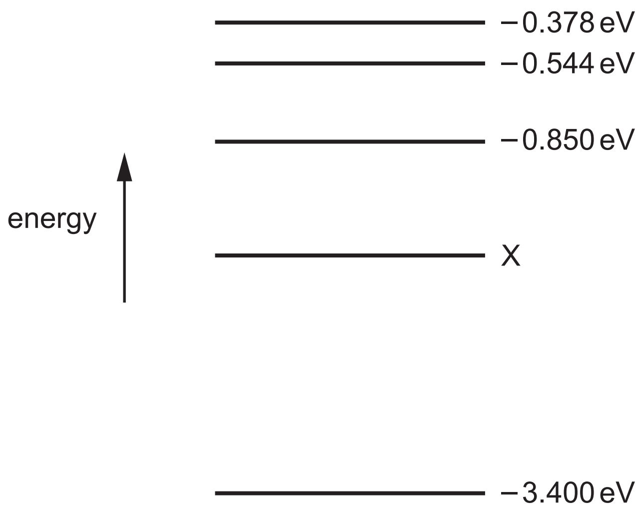

Fig. 9.2 (not to scale)

Show that the energy level X is −1.51 eV.

[3]

(b) The same part of the emission spectrum from hydrogen as in **(a)**, observed in light from stars in a distant galaxy, is shown in Fig. 9.3. The numbers indicate the wavelengths in nm.

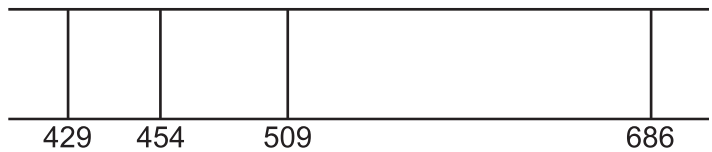

Fig. 9.3

The spectrum shows the same pattern as Fig. 9.1 but with different wavelengths.

(i) State the name of the phenomenon that gives rise to the change in the wavelengths.

.... [1]

(ii) State what this phenomenon shows about the motion of the galaxy.

.... [1]

(iii) Use one of the lines in Fig. 9.1, and the corresponding line in Fig. 9.3, to determine the speed of the distant galaxy relative to the observer.

speed = ... m s^{-1} [3]

(c) The galaxy in **(b)** is known to be a distance of 5.7×10^{24} m from the Earth.

Use your answer in **(b)(iii)** to determine a value for the Hubble constant H_0.

H_0 = ... s^{-1} [2]

[Total: 12]