22. Quantum Physics

22.4 Energy levels in atoms and line spectra

Paper 4

Question Paper

1 Fig. 8.1 shows part of the emission spectrum of visible radiation emitted by hydrogen gas in a star in a distant galaxy.

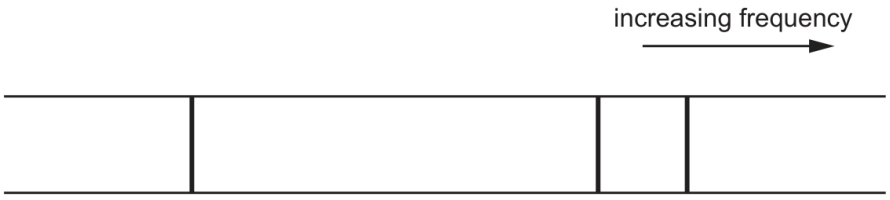


Fig. 8.1

The galaxy is moving away from the Earth at a speed of $6.2 \times 10^6\,\text{m s}^{-1}$.

(b) The lines in Fig. 8.1 correspond to electron transitions down to the energy level –3.40 eV. One of the lines represents emitted radiation of wavelength 488 nm.

(ii) Determine the energy, in eV, of the energy level from which the electron transition originates to cause the emission of this radiation.

energy level = ... eV [2]

2 Fig. 8.1 shows the lowest four energy levels of an electron in an isolated atom.

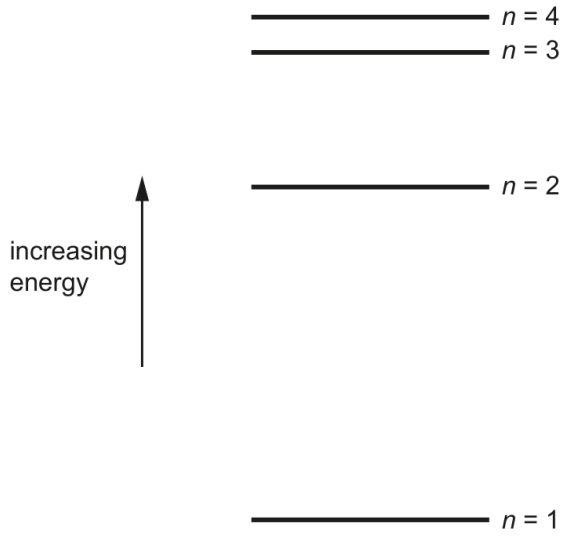


Fig. 8.1

Fig. 8.2 shows the lines in the emission spectrum of the atom that correspond to the transitions of the electron from $n = 3$ to $n = 1$ and from $n = 4$ to $n = 1$.

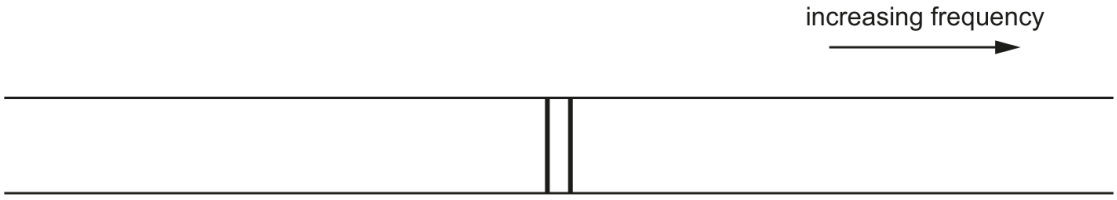


Fig. 8.2

(a) Explain, with reference to photons, why there is a single frequency of electromagnetic radiation that corresponds to each of these transitions.

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..... [2]

(b) **(i)** On Fig. 8.2, draw a line that corresponds to the transition of the electron from $n = 2$ to $n = 1$. Label this line A. [2]

(ii) On Fig. 8.2, draw a line that corresponds to the transition of the electron from $n = 3$ to $n = 2$. Label this line B. [2]

(c) The frequency of radiation represented by line A is f_A.
The frequency of radiation represented by line B is f_B.
The energy of the ground state ($n = 1$) is E_1.

Determine an expression, in terms of f_A, f_B, E_1 and the Planck constant h, for the energy E_3 of the energy level $n = 3$.

$E_3 =$ ..... [2]

3 **(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.

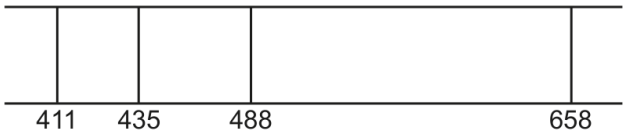


Fig. 9.1

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

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..... [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.

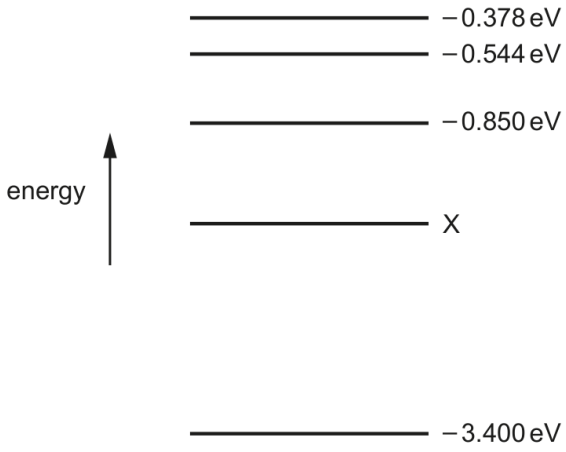


Fig. 9.2 (not to scale)

Show that the energy level X is –1.51 eV.

[3]

4 **(a)** White light passes through a cloud of cool low-pressure gas, as illustrated in Fig. 10.1.

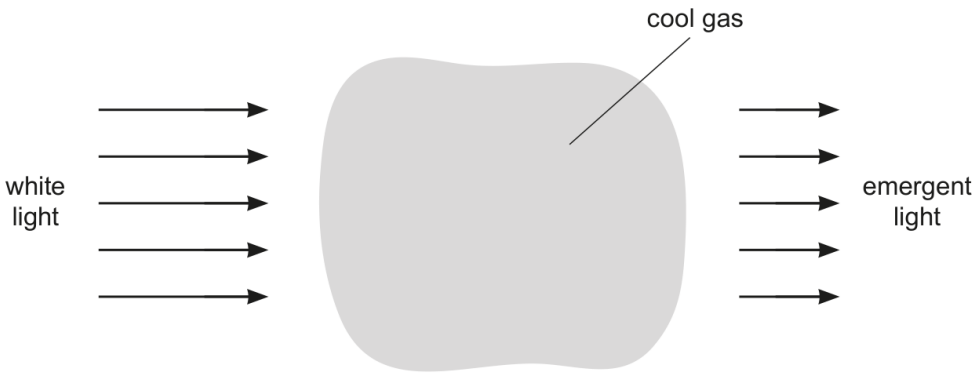


Fig. 10.1

For light that has passed through the gas, its continuous spectrum is seen to contain a number of darker lines.

Use the concept of discrete electron energy levels to explain the existence of these darker lines.

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..... [4]

5 **(b)** Describe the appearance of a visible line emission spectrum, as seen using a diffraction grating.

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.....[2]

(c) The lowest electron energy levels in an isolated hydrogen atom are shown in Fig. 11.1.

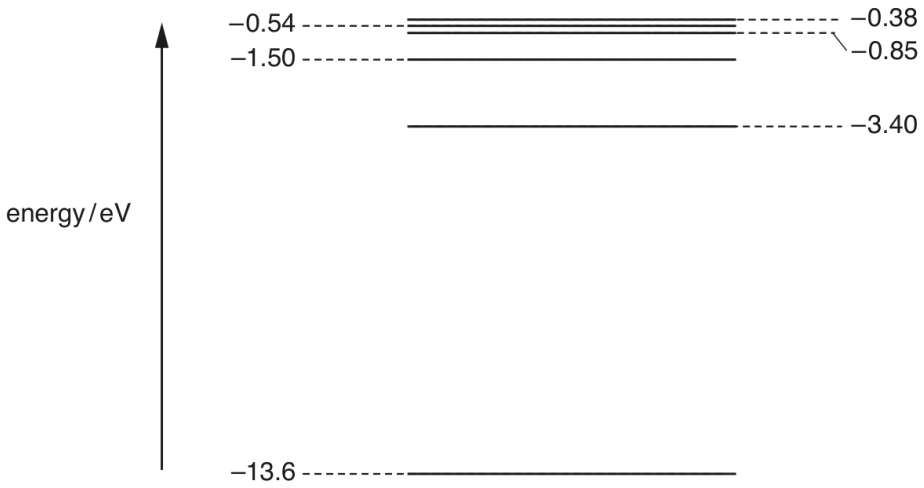


Fig. 11.1 (not to scale)

(i) An electron is initially at the energy level –0.85 eV. State the total number of different wavelengths that may be emitted as the electron de-excites (loses energy).

number = ... [1]

(ii) Photons resulting from electron de-excitation from the –0.85 eV energy level are incident on the surface of a sample of platinum.

Platinum has a work function energy of 5.6 eV.

Determine

1. the maximum kinetic energy, in eV, of a photoelectron emitted from the surface of the platinum,

maximum energy = ... eV [2]

2. the wavelength of the photon producing the photoelectron in **(ii) part 1**.

wavelength = ... m [3]