7 **(a)** Fig. 7.1 shows a high voltage supply set up to produce energetic electrons with kinetic energies of 3.50 eV in a discharge tube. These electrons bombard the cool sodium gas in the discharge tube, giving rise to a spectrum of transmitted light. The light passes through a diffraction grating to reach a detector.

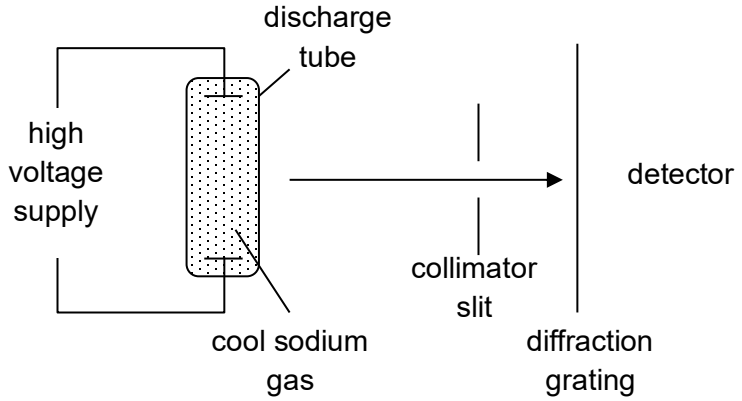

Fig. 7.1

Some electron energy levels in a sodium atom are illustrated in Fig. 7.2. The energy level n = 1 represents the ground state.

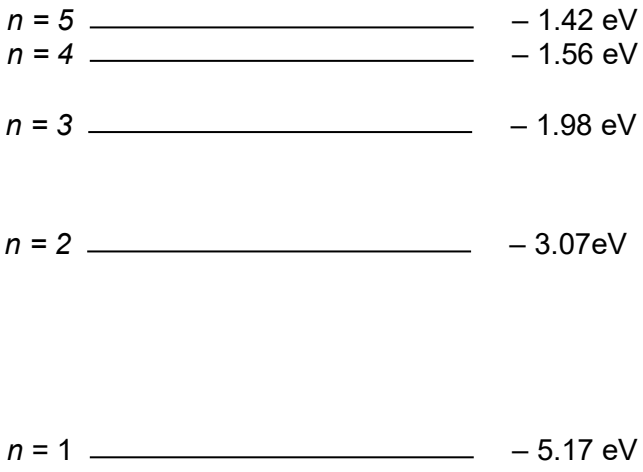

Fig. 7.2

(i) Deduce the maximum number of spectral lines that could be detected.

number of spectral lines = …… [1]

(ii) Calculate the frequency of the photon emitted when an electron in energy level n = 2 transits to the ground state.

frequency = …… Hz [2]

(iii) A cool gas X is placed between the discharge tube and the collimator slit as shown in Fig. 7.3.

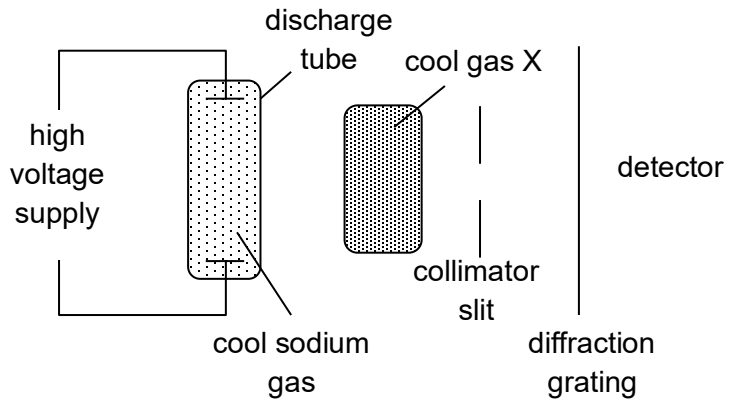

Fig. 7.3

Fig. 7.4 shows the electron energy levels in an atom of X.

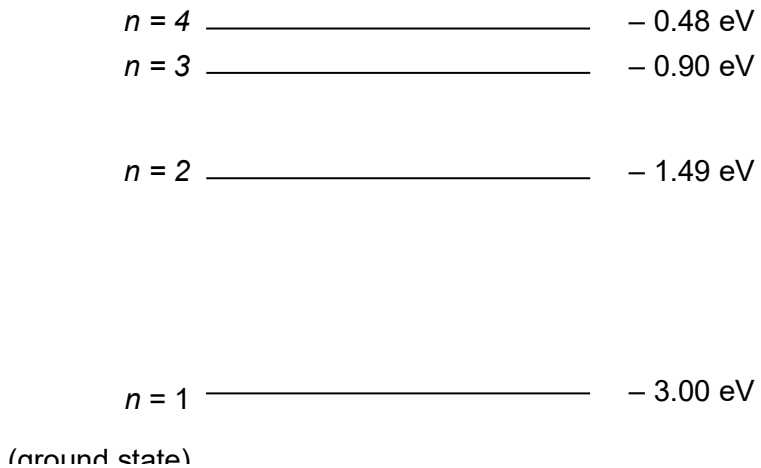

Fig. 7.4

Photons emitted from the sodium gas due to the transitions in **a(ii)** are absorbed by X.

State if the following transitions can occur due to this absorption.
Explain your answer.

1. from ground state to n = 2: ……

2. from ground state to n = 3: ……

……..……..

……..……..

[3]

……..……

(iv) When the radiation from a nucleus is examined, it is found that it too has a line emission spectrum. These lines correspond to radiation with frequencies in the gamma range.

Deduce two conclusions that can be made from this observation.

……..……...

……..……...

……..……...

……..…… [2]

(b) Yttrium-90 is a radioactive isotope often used in cancer treatment. As it undergoes β-decay, it emits high-energy electrons.

(i) When a sample of Yttrium-90 isotope is placed in a lead container, X-ray radiation with a range of energies is detected from the container walls.

Explain the phenomenon.

……..……...

……..……...

……..……...

……..……...

……..…… [3]

(ii) Determine the momentum of an X-ray photons with an energy of 100 keV.

momentum = …… kg m s^{-1} [3]

(iii) The rate of X-ray photons, with energy of 100 keV, incident on a surface is 1.6×10^5 s^{-1}.

Assuming that all these photons are absorbed by the surface, calculate the force on the surface.

force = …… N [2]

(c) State an experiment and explain how it shows that electromagnetic radiation has a particulate nature.

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……..……..…… [4]