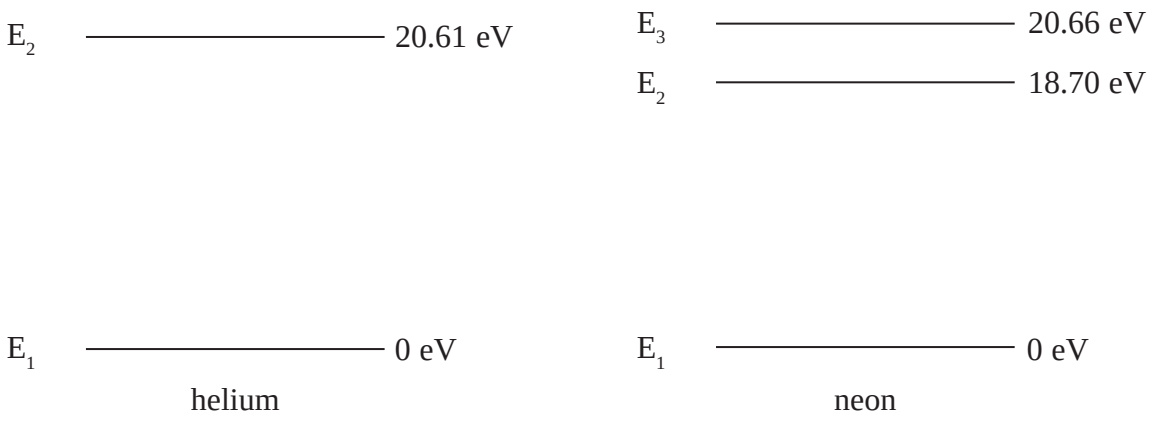
1 A helium-neon gas laser is often used in the laboratory as a source of high intensity, coherent, monochromatic light.

The diagram shows some of the energy levels above the ground level E_3 for helium atoms and for neon atoms. The highest shown levels for helium atoms and neon atoms are almost identical.



Helium atoms in the gas are excited to level E_2 by the current passing through the laser. They collide at high speed with neon atoms. Because the energies are so similar, the energy is transferred from the helium atoms to the neon atoms. The neon atoms become excited in turn to level E_3. As the neon atoms subsequently drop to level E_2 they emit photons.

(a) Explain what is meant by a photon.

(2)

(b) Calculate the frequency of the photons produced as the neon atoms drop from level E_3 to level E_2.

(3)

Frequency =

(c) An electron in level E_3 of neon has 0.05 eV more energy than an electron in level E_2 of helium.

Suggest the source of the energy to make up this difference.

(1)

(d) The photograph shows a device for making a vertical slit with variable width.

When the slit is fully open a laser beam is shone through it and a single point of light is seen on a screen.

As the slit is reduced in width the point of light becomes a horizontal line that gets longer as the slit gets narrower.

Explain this observation.

(3)

(Total for Question = 9 marks)

2 (a) Describe the key observations of the alpha particle scattering experiments which led to Rutherford's nuclear model of the atom.

(3)

(b) Experiments at Stanford University's linear accelerator (linac) accelerate electrons up to energies of 20 GeV.

(i) State the main features of a linac.

(3)

(ii) Calculate the de Broglie wavelength of 20 GeV electrons. At these energies, the following relativistic equation applies $E \quad pc$.

(3)

.....

.....

.....

De Broglie wavelength .....

(iii) Suggest why these electrons would be particularly useful for investigating nuclear structure.

(1)

.....

.....

.....

(iv) These electrons can be aimed at a hydrogen target. Some of these electrons are scattered at large angles by the protons whilst others pass straight through.

Suggest what this tells you about the structure of a proton.

(2)

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.....

(v) The scattering process is inelastic. What is meant by an inelastic collision?

(1)

.....

.....

(Total for Question 13 marks)

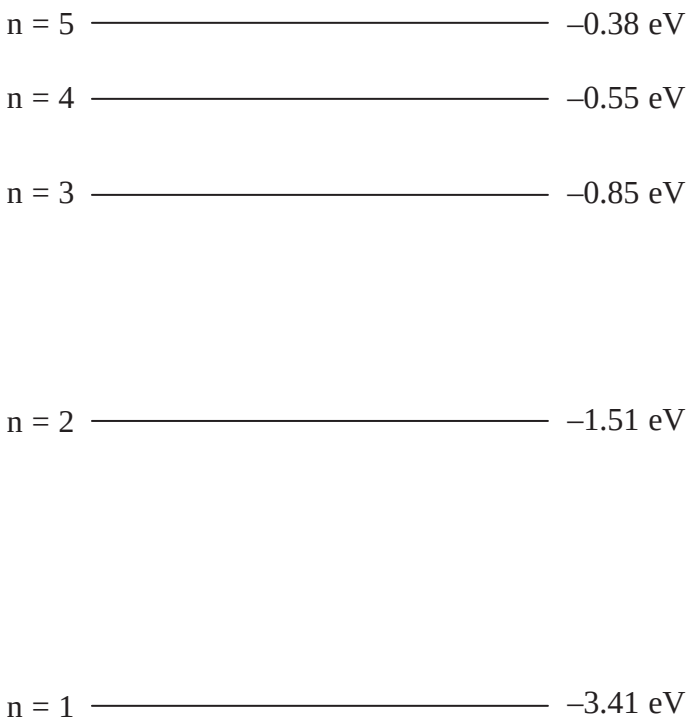
3 Helium was first discovered because of dark lines observed in the continuous spectrum of light from the Sun. The lines were caused by a few specific frequencies of light in the spectrum being present at very much lower intensity than the rest.

Scientists deduced that this was due to an unknown element in the Sun's atmosphere.

(a) Explain how helium in the Sun's atmosphere caused this set of dark lines.

(5)

(b) The diagram shows some of the energy levels for an atom of another element.



(i) Determine which energy levels are associated with photons of frequency 4.6×10^{14} Hz.

(4)

(ii) Suggest why the energy levels all have a negative value.

(2)

(c) Lines such as those described in (a) can be used to determine the motion of stars relative to the Earth.

Suggest how these lines may be used to determine the motion of stars.

(3)

(Total for Question = 14 marks)

4 (a) State what is meant by the de Broglie wavelength.

(2)

(b) An electron is accelerated from rest, in a vacuum, through a potential difference of 500 V.

(i) Show that the final momentum of the electron is about 1×10^{-23} N s.

(3)

(ii) Calculate the de Broglie wavelength for this electron.

(2)

de Broglie wavelength =

(Total for Question = 7 marks)