IB · SL · Physics

3 hours 12 questions

Structured Questions

Structure of the Atom

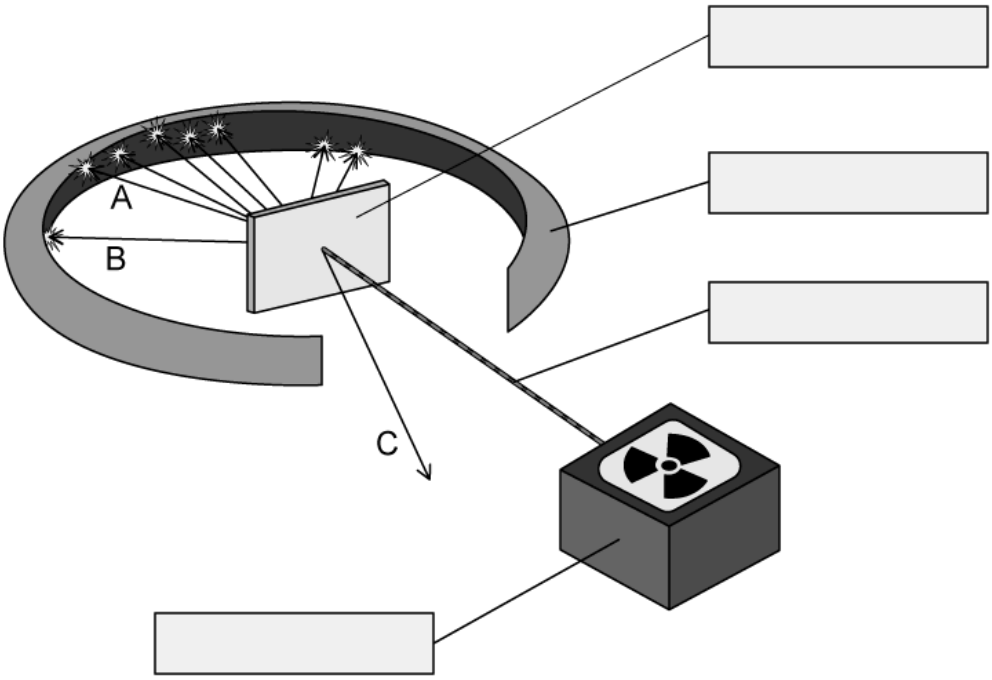
Rutherford's Gold Foil Experiment / Nuclear Notation / Emission & Absorption Spectrum / Photon Energy

Easy (4 questions)	/56
Medium (4 questions)	/55
Hard (4 questions)	/50
Total Marks	**/161**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) The diagram shows the experimental set-up of Rutherford's gold foil experiment.



Identify the equipment required by adding words to the empty labels.

....

....

....

....

(4 marks)

(b) Rutherford made three observations from his gold foil experiment.

Describe each observation labelled A, B and C.

....

(3 marks)

(c) Describe the property of atoms shown by each observation A, B and C in part (b).

(4 marks)

2 (a) Describe how an emission spectra is created.

....

....

(2 marks)

(b) Explain the process involved in obtaining an absorption spectra.

....

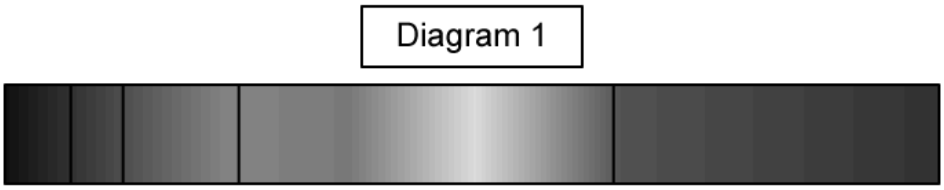
....

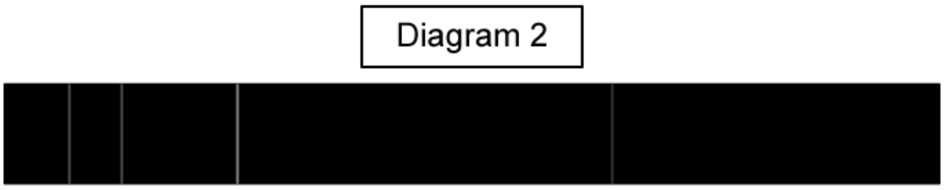
....

....

(4 marks)

(c) The absorption and emission spectra for hydrogen are shown below.





Identify which is the emission and which is the absorption spectra and give a reason for each choice.

....

....

(4 marks)

(d) State how a substance can be identified by its emission line spectra.

(1 mark)

3 (a) Rutherford's gold foil experiment involves an α particle source fired at a gold foil inside a vacuum chamber.

Describe how air molecules can affect the experiment.

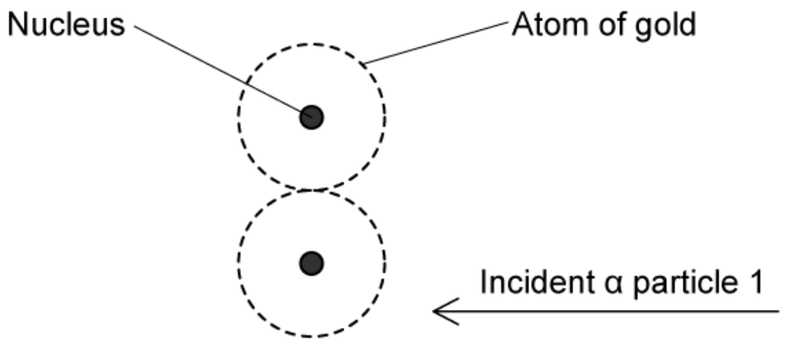
....

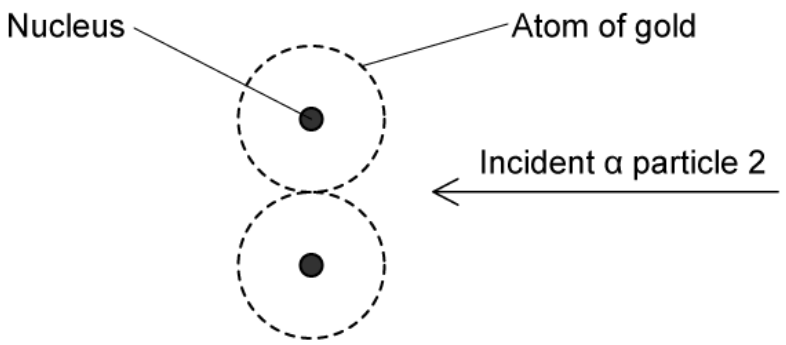
....

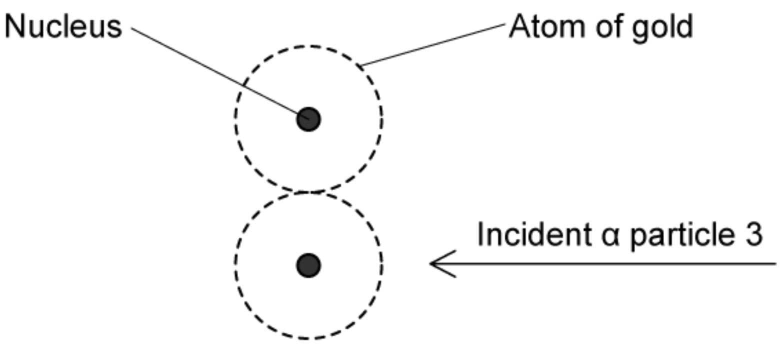
(2 marks)

(b) The diagrams show three positions of α particles incident on a gold foil.

Draw the complete path followed by each of the α particles shown.







(3 marks)

(c) Sketch a labelled diagram showing the experimental arrangement of the apparatus used by Rutherford.

This must include the α particle source, gold foil target and α particle detector.

(4 marks)

(d) State the three observations made by Rutherford in his gold foil experiment and their significance.

(6 marks)

4 (a) Match, by drawing a line, the words with their correct definitions.

Ionisation	Fundamental particles that make up all forms of electromagnetic radiation
Photon	A group of atoms containing the same number of protons and neutrons
Nuclide	The electron has gained enough energy to be removed from the atom entirely
Isotope	An atom of the same element that has an equal number of protons but a different number of neutrons

....

....

....

....

(4 marks)

(b) The energy of a photon can be calculated using the equation

$$E = \frac{hc}{\lambda}$$

Define the following terms and give the unit:

(i) *h*

[2]

(ii) *c*

[2]

(iii) λ

[2]

(6 marks)

(c) Calculate the wavelength of a photon with an energy of 1.44×10^{-19} J.

(2 marks)

(d) (i) Complete the gaps in the following paragraph by writing the correct words on the line.

Electrons in an atom can only have specific energies. These energies are called ________ ________ ______ .

Normally, electrons occupy the ______ energy level available. This is known as the _________ _________.

Electrons can gain energy and move up the energy levels by ____________ energy.

[4]

(ii) Underline the processes that allow an electron to move up an energy level.

Collisions with other atoms or electrons Releasing a photon Radioactive decay Absorbing a photon Changing colour Emitting a neutrino

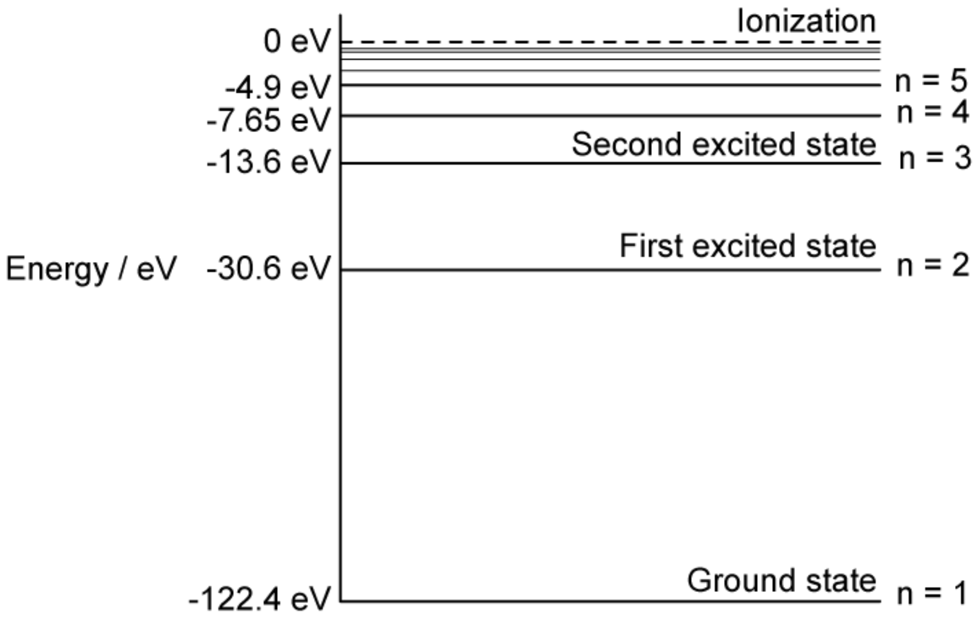
A physical source, such as heat

[3]

(7 marks)

Medium Questions

1 (a) The energy levels of a hydrogen atom are shown below.



Calculate the wavelength of radiation emitted when an electron falls from level n = 5 to the ground state in the hydrogen atom.

....

....

....

....

(4 marks)

(b) When an electron of energy 1.88×10^{-17} J collides with a hydrogen atom, photons of ten different energies are emitted.

Sketch arrows on the diagram from part (a) to show the transitions responsible for these photons.

(4 marks)

(c) Calculate the wavelength of the photon with the largest energy. Give your answer to an appropriate number of significant figures.

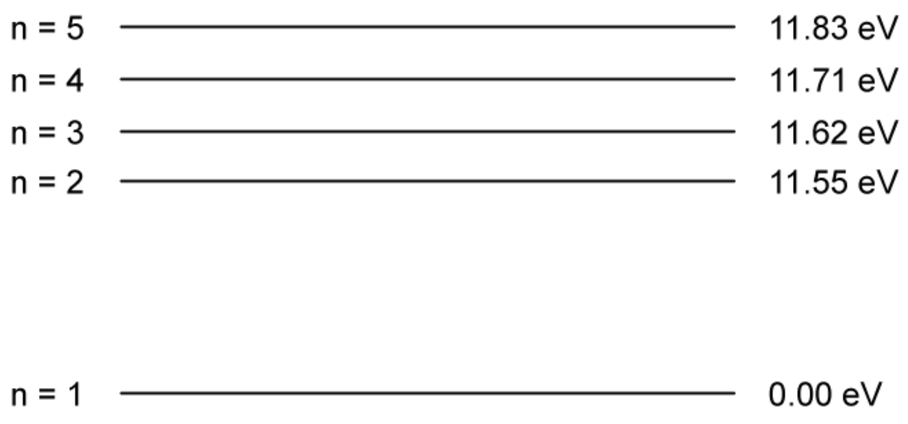
(3 marks)

(d) One way to excite a hydrogen atom is by the absorption of a photon.

Explain why, for a particular transition, the photon must have an exact amount of energy.

(2 marks)

2 (a) The lowest energy levels of an argon atom are shown below.



Calculate the wavelength of an emitted photon due to the transition level n = 5 to level n = 3.

(3 marks)

(b) Draw arrows on the diagram above to show the electron transitions which emit a photon with a longer wavelength than that emitted in the transition from $n = 5$ to $n = 3$.

(4 marks)

(c) A fluorescent tube is filled with argon gas at low pressure. When the argon atoms are excited, they emit photons.

Explain how the excited argon atoms emit photons.

....

....

(2 marks)

(d) Explain how the coating on the inside surface of the glass in a fluorescent tube helps to emit photons in the visible spectrum.

....

....

....

(3 marks)

3 (a) In a HeNe laser, electrons collide with helium atoms. The ground state of a helium is labelled as 1*s* and the next energy level is labelled 2*s*.

When an electrons de-excite from 2*s* to 1*s* in helium, photons are emitted with a wavelength of 58.4 nm.

Calculate the energy difference of this transition, giving your answer in eV.

....

....

....

(3 marks)

(b) An electron collides with a helium in its ground state, causing an electron to transition from 1*s* to 2*s*. The electron initially has 45.0 eV of kinetic energy.

Calculate the electron's kinetic energy after the collision.

....

....

(2 marks)

(c) Explain why it is not possible for the same electron from (b) to collide with the ground state helium atom and be left with 40.0 eV of kinetic energy.

....

....

....

(3 marks)

(d) Helium and neon coincidentally have very similar energy gaps for certain transitions, allowing one atom to cause an excitation in the other.

The excited helium atom from part (b) then collides with a ground state neon atom. The neon atom becomes excited and subsequently emits two photons in order to return to its ground state.

(i) If the helium is left back in its ground state after the collision, determine the amount of energy transferred to the neon atom.

[1]

(ii) If one photon has an energy of 1.96 eV, calculate the wavelength of the other.

[4]

....

....

....

....

....

(5 marks)

4 (a) Rutherford used the scattering of α particles to provide evidence for the structure of the atom. The apparatus includes a narrow beam of α particles fired at a very thin sheet of gold foil inside a vacuum chamber.

Explain why it is essential to use:

(i) a vacuum in the chamber

[1]

(ii) a very thin sheet of gold foil

[1]

(iii) a narrow beam of alpha particles

[1]

....

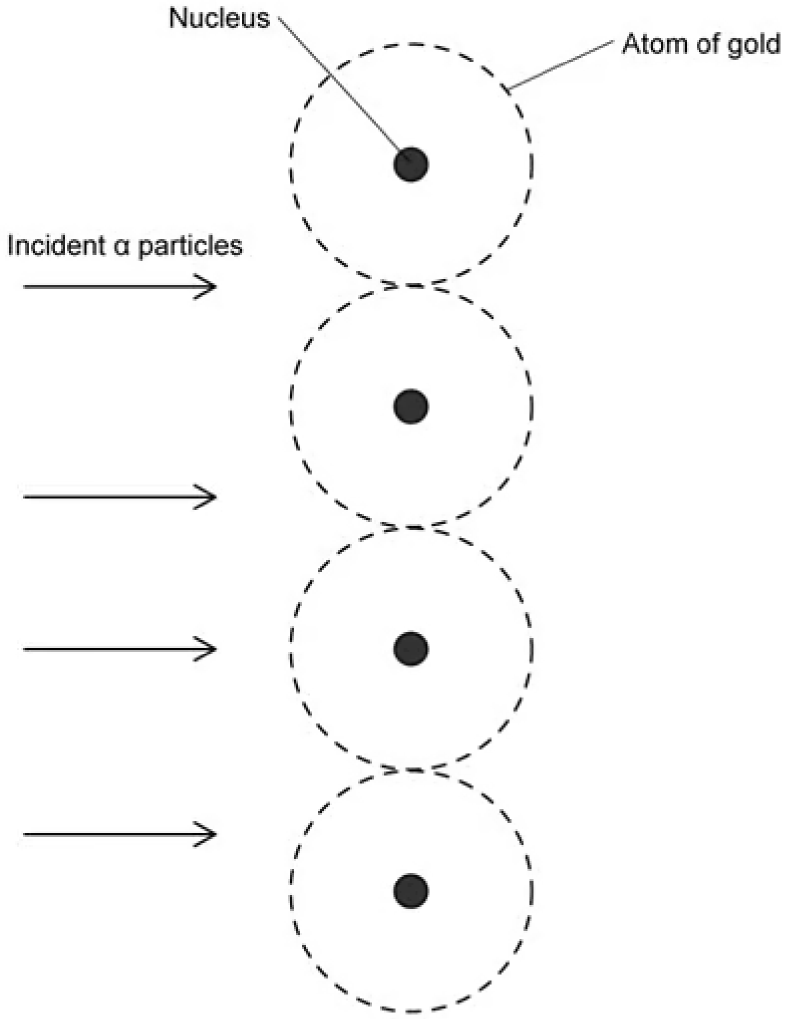
....

....

(3 marks)

(b) The diagram shows α particles incident on a layer of atoms in a gold foil.

On the diagram, draw and complete the paths followed by **each** of the α particles shown.



....

....

....

(3 marks)

(c) Outline the results of the scattering experiment by explaining:

(i) the main observations of the scattering experiment

[2]

(ii) the significance of each observation

[3]

....

(5 marks)

(d) The Thomson model of the atom preceded Rutherford's model. In the Thomson model, the atom was imagined as a sphere of positive charge of diameter 10^{-10} m containing electrons moving within the sphere.

Thomson's model could explain some of the results of the Rutherford experiment, but not all.

Explain

(i) why, at small deflections, Rutherford's experiment can be explained by Thomson's model but not at large deflections

[3]

(ii) why Rutherford's model of the atom can account for the results at both small and large deflections

[3]

(6 marks)

Hard Questions

1 (a) Transitions between three energy levels in a particular atom give rise to three spectral lines.

In increasing magnitudes, these are related to the wavelengths, λ_a, λ_b, and λ_c,

Use a diagram to show that the equation that relates λ_a, λ_b, and λ_c is:

$$\frac{1}{\lambda_a} = \frac{1}{\lambda_b} + \frac{1}{\lambda_c}$$

....

....

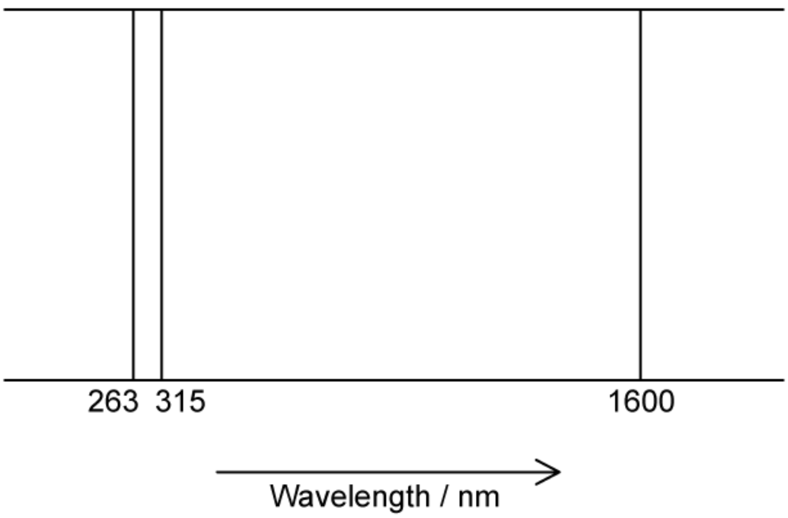
....

....

....

(5 marks)

(b) An atom has a ground state energy of −6.60 eV.



Sketch a diagram of the possible energy levels for the atomic line spectra to show that the wavelengths λ_a, λ_b, and λ_c satisfy the equation.

$$\frac{1}{\lambda_a} = \frac{1}{\lambda_b} + \frac{1}{\lambda_c}$$

(5 marks)

(c) Describe the nature of the atomic line spectra shown in part (b).

(3 marks)

(d) Sir William Herschel discovered infrared radiation in 1800. The equipment he used is listed below:

- Glass prism
- Blackout curtains with an envelope slit to allow natural light through
- Thermometers

Explain how he discovered infrared radiation using this equipment.

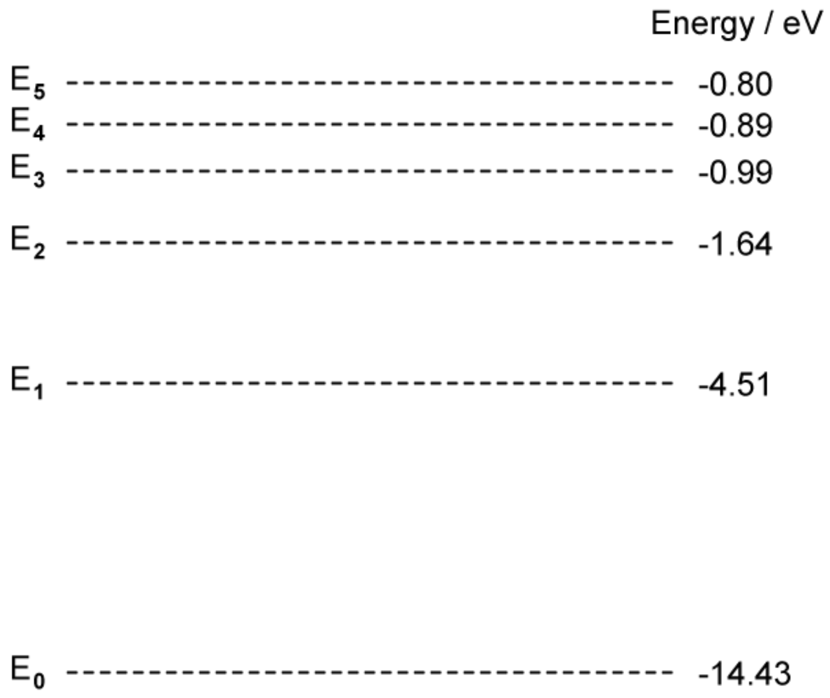
....

....

....

(3 marks)

2 (a) Two students debate which electron energy transition causes a photon of infrared radiation to be emitted from excited hydrogen atoms.



Student 1 thinks it's the transition E_5 to E_4 .

Student 2 thinks it's the transition E_1 to E_0.

State and explain which student is correct.

....

....

....

(3 marks)

(b) In a new type of special effects tube covered in a special infrared absorbent coating, the hydrogen atoms inside are excited. This leads to a series of events which result in the emission of photons in the visible region of the electromagnetic spectrum from the coating of the tube.

Describe the series of events, following the excitation of the atoms, which results in the emission of visible photons.

(5 marks)

(c) Discuss the meaning of the *first molar ionisation energy*.

(3 marks)

3 (a) An electron is accelerated through an electric field between two parallel plates. The plates are separated by 2.2 cm and the electric field has a strength of 6.37×10^2 V m^{-1}.

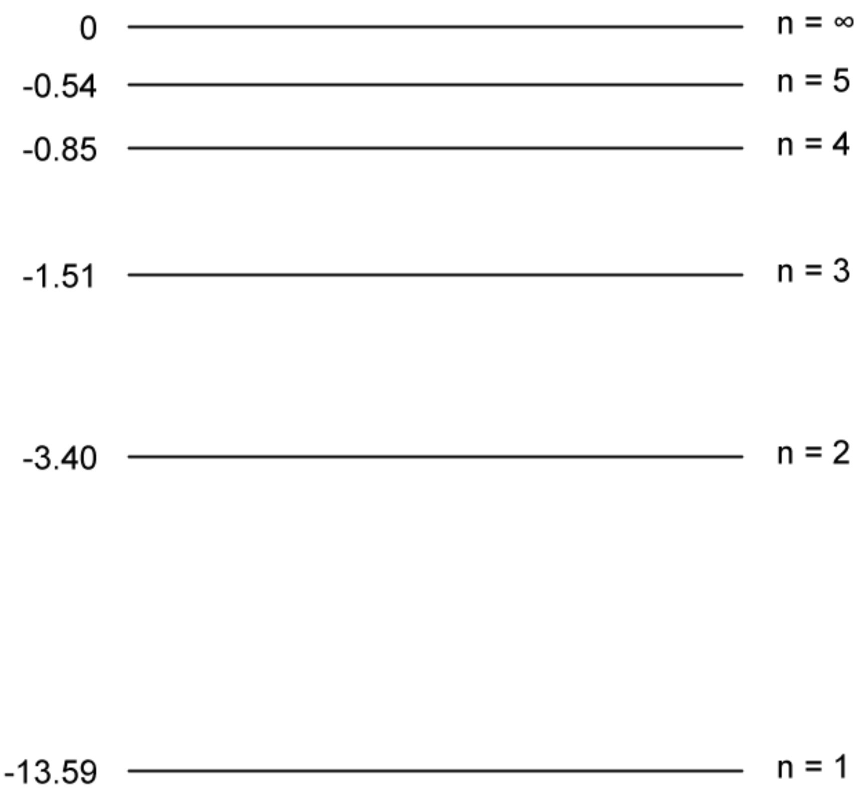
Determine the kinetic energy of the electron in eV.

....

....

(2 marks)

(b) The electron then hits a hydrogen atom in its ground state and excites it.



(i) Explain what is meant by excitation

[1]

(ii) Determine the energy level the electron from the hydrogen is excited to

[1]

....

....

(2 marks)

(c) Determine the range of wavelengths of all the photons that could be emitted as this electron returns to its ground state.

....

....

....

....

....

(5 marks)

4 (a) Transitions between three energy levels in a particular atom give rise to three spectral lines. In decreasing magnitudes, these are f_1, f_2 and f_3.

The equation which relates f_1, f_2 and f_3 is:

$$f_1 = f_2 + f_3$$

Explain, including through the use of a sketch, how this equation relates f_1, f_2 and f_3.

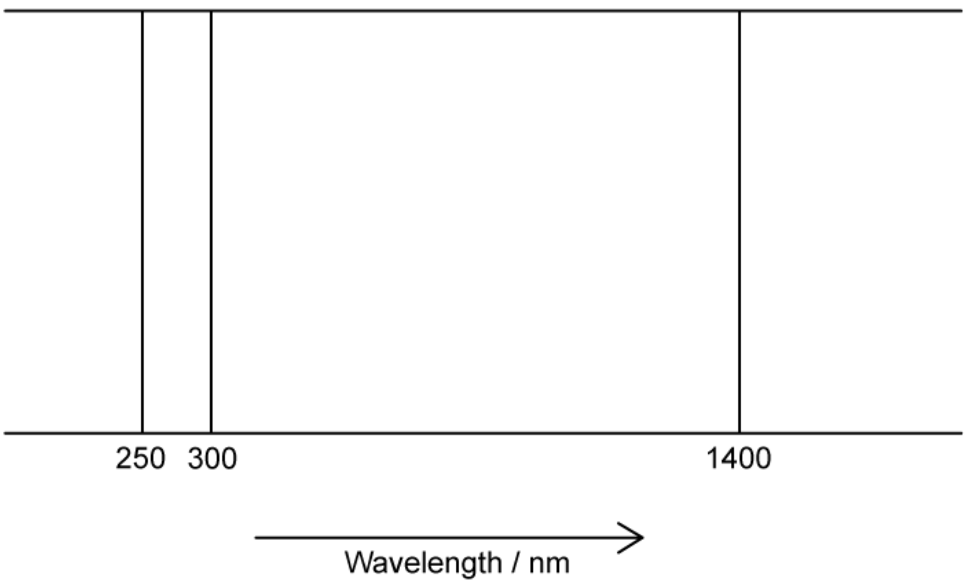
....

....

....

(3 marks)

(b) A different atom has a complete line emission spectra with a ground state energy of –10.0 eV. is:



Sketch and label a diagram of the possible energy levels for the atomic line spectra shown.

....

....

(5 marks)

(c) Explain the significance of an electron at an energy level of 0 eV.

(3 marks)

(d) (i) Explain the statement 'the first excitation energy of the hydrogen atom is 10.2 eV'

[1]

(ii) The ground state of hydrogen is –13.6 eV. Calculate the speed of the slowest electron that could cause this excitation of a hydrogen atom.

[2]

(3 marks)