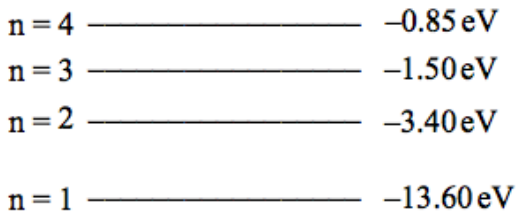
1)

1 **Figure 1** shows part of an energy level diagram for a hydrogen atom.

Figure 1



1 (a) The level, n = 1, is the ground state of the atom.
State the ionisation energy of the atom in eV.

answer = ... eV
(1 mark)

1 (b) When an electron of energy 12.1 eV collides with the atom, photons of three different energies are emitted.

1 (b) (i) On **Figure 1** show with arrows the transitions responsible for these photons.
(3 marks)

1 (b) (ii) Calculate the wavelength of the photon with the smallest energy. Give your answer to an appropriate number of significant figures.

answer =..... m
(5 marks)

2)

(a) State what is meant by the wave-particle duality of electrons.

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(1 mark)

(b) Electrons of wavelength 1.2×10^{-10}m are required to investigate the spacing between planes of atoms in a crystal.

(b) (i) Calculate the momentum of an electron of this wavelength stating an appropriate unit.

momentum of electron = ...

(3 marks)

(b) (ii) Calculate the speed of such an electron.

speed of electron = ... m s^{-1}

(2 marks)

(b) (iii) Calculate the kinetic energy of such an electron.

kinetic energy of electron = ... J

(2 marks)

3)

(a) A fluorescent tube is filled with mercury vapour at low pressure. In order to emit electromagnetic radiation the mercury atoms must first be *excited*.

(a) (i) What is meant by an excited atom?

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(1 mark)

(a) (ii) Describe the process by which mercury atoms become excited in a fluorescent tube.

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(3 marks)

(a) (iii) What is the purpose of the coating on the inside surface of the glass in a fluorescent tube?

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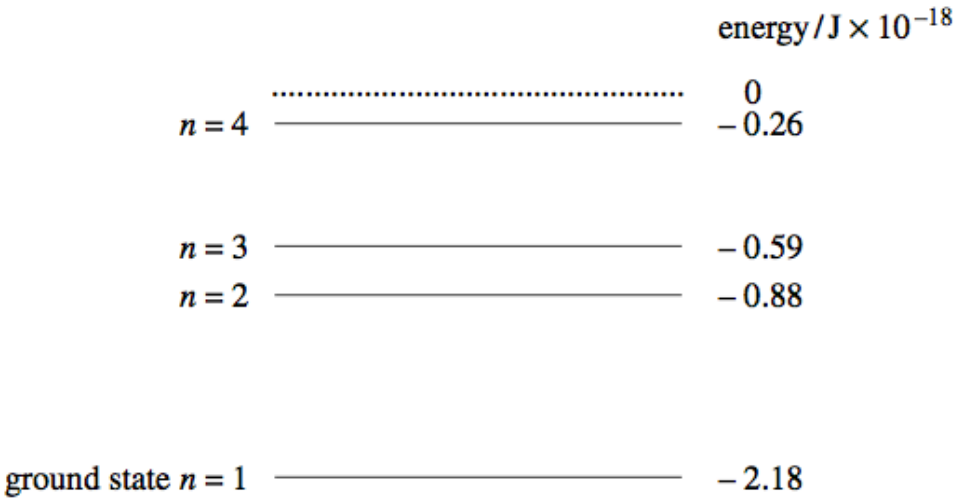
(3 marks)

(b) The lowest energy levels of a mercury atom are shown in **Figure 1**. The diagram is **not** to scale.

Figure 1



(b) (i) Calculate the frequency of an emitted photon due to the transition level $n = 4$ to level $n = 3$.

answer = ... Hz

(3 marks)

(b) (ii) Draw an arrow on the **Figure 1** to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

(2 marks)

4)

(a) When free electrons collide with atoms in their *ground state*, the atoms can be excited or ionised.

(a) (i) State what is meant by ground state.

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(1 mark)

(a) (ii) Explain the difference between excitation and ionisation.

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(3 marks)

(b) An atom can also become excited by the absorption of photons. Explain why only photons of certain frequencies cause excitation in a particular atom.

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(4 marks)

(c) The ionisation energy of hydrogen is 13.6 eV. Calculate the minimum frequency necessary for a photon to cause the ionisation of a hydrogen atom. Give your answer to an appropriate number of significant figures.

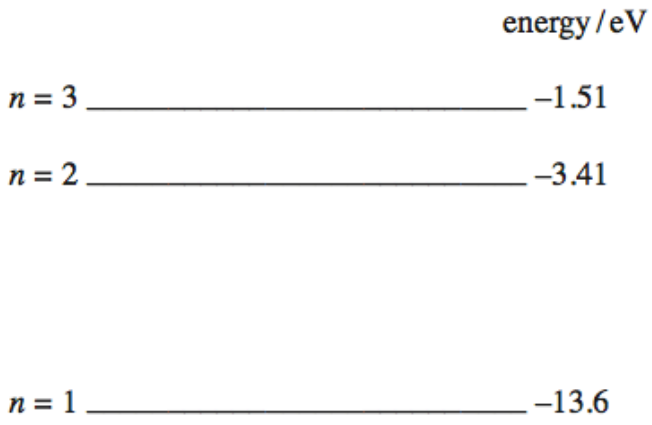
answer .....Hz

(4 marks)

5)

Figure 1 shows the lowest three energy levels of a hydrogen atom.

Figure 1



(a) An electron is incident on a hydrogen atom. As a result an electron in the ground state of the hydrogen atom is excited to the $n = 2$ energy level. The atom then emits a photon of a characteristic frequency.

(a) (i) Explain why the electron in the ground state becomes excited to the $n = 2$ energy level.

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(2 marks)

(a) (ii) Calculate the frequency of the photon.

frequency = ... Hz

(3 marks)

(a) (iii) The initial kinetic energy of the incident electron is 1.70×10^{-18} J.

Calculate its kinetic energy after the collision.

kinetic energy = ... J

(2 marks)

(a) (iv) Show that the incident electron cannot excite the electron in the ground state to the $n = 3$ energy level.

(2 marks)

(b) When electrons in the ground state of hydrogen atoms are excited to the $n = 3$ energy level, photons of more than one frequency are subsequently released.

(b) (i) Explain why different frequencies are possible.

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(1 mark)

(b) (ii) State and explain how many possible frequencies could be produced.

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(2 marks)

6)

Electrons exhibit *wave properties*.

(a) What phenomenon can be used to demonstrate the wave properties of electrons? Details of any apparatus used are not required.

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(1 mark)

(b) Calculate the de Broglie wavelength of electrons travelling at a speed of 4.50×10^5 m s^{-1}.

answer = ... m

(2 marks)

(c) The muon has a mass equal to 207 times the mass of an electron.
Calculate the speed of muons with the same de Broglie wavelength as the electrons in part (b).

answer = ... m s^{-1}

(3 marks)

7)

(a) What phenomenon can be used to demonstrate the wave properties of electrons?

[1 mark]

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(b) Calculate the wavelength of electrons travelling at a speed of $2.5 \times 10^5\,\text{m s}^{-1}$.

Give your answer to an appropriate number of significant figures.

[3 marks]

wavelength ..... m

(c) Calculate the speed of muons with the same wavelength as these electrons.

mass of muon = 207 × mass of electron

[2 marks]

speed ..... m s^{-1}

8)

(a) A fluorescent tube is filled with mercury vapour at low pressure. After mercury atoms have been excited they emit photons.

(a) (i) In which part of the electromagnetic spectrum are these photons?

[1 mark]

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(a) (ii) What is meant by an excited mercury atom?

[1 mark]

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(a) (iii) How do the mercury atoms in the fluorescent tube become excited?

[2 marks]

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(a) (iv) Why do the excited mercury atoms emit photons of characteristic frequencies?

[3 marks]

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(b) The wavelength of some of the photons emitted by excited mercury atoms is 254 nm.

(b) (i) Calculate the frequency of the photons.

[2 marks]

frequency ..... Hz

(b) (ii) Calculate the energy of the photons in electron volts (eV).

[2 marks]

energy ..... eV

(c) Explain how the coating on the inside of a fluorescent tube emits visible light.

[2 marks]

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9)

Electrons with a range of kinetic energies strike atoms of a particular element which are in their *ground state*. As a result of these collisions photons of various frequencies are emitted by some of the atoms.

(a) Explain what is meant by the ground state of an atom and describe the process that is taking place in the atoms emitting photons.

The quality of your written communication will be assessed in this question.

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(6 marks)

(b) The table below shows how the kinetic energies of electrons with different incident energies may change after collisions with atoms.

	kinetic energy of electron before collision/eV	**kinetic energy of electron after collision/eV**
First electron	5.5	5.5
Second electron	9.0	1.0

(b) (i) Explain why one of the electrons loses energy while the other does not.

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(2 marks)

(b) (ii) Convert the energy of 9.0 eV into joules

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(2 marks)

(b) (iii) Calculate the **maximum** frequency of the photon emitted when the 9.0 ev electron collides with an atom.

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answer.....Hz

(3 marks)

10)

(a) Line spectra were observed before they could be explained by theory. We now know that photons of characteristic frequency are emitted when the vapour of an element is bombarded by energetic electrons. The spectrum of the light emitted contains lines, each of a definite wavelength.

Explain how

- the bombarding electrons cause the atoms of the vapour to emit photons
- the existence of a spectrum consisting of lines of a definite frequency supports the view that atoms have discrete energy levels.

The quality of your written communication will be assessed in this question.

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(6 marks)

(b) The *ionisation energy* of a hydrogen atom is 13.6 eV.

(b) (i) State what is meant by the ionisation energy of hydrogen.

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(2 marks)

(b) (ii) Express the ionisation energy of hydrogen in joules, giving your answer to an appropriate number of significant figures.

answer = ... J

(3 marks)