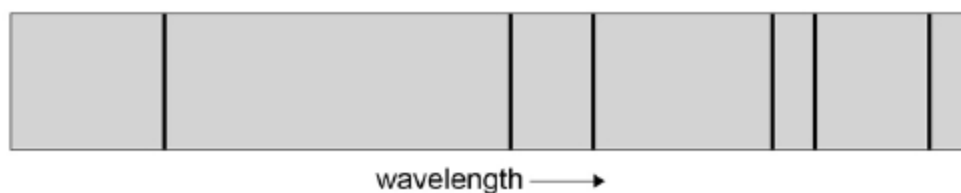


1

The diagram below shows the line spectrum of a gas.



Explain how line spectra are produced. In your answer you should describe:

- how the collisions of charged particles with gas atoms can cause the atoms to emit photons.
- how spectral lines are explained by the concept of discrete energy levels.

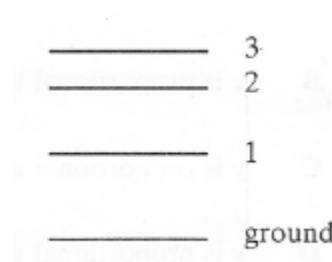
(Total 6 marks)

2

The values of the lowest three energy levels in a particular atom are shown in the table.

The diagram shows these levels together with the ground state of the atom.

Level	Energy/eV
3	-0.85
2	-1.51
1	-3.39



When an electron moves from level 3 to level 1, radiation of frequency 6.2×10^{14} Hz is emitted.

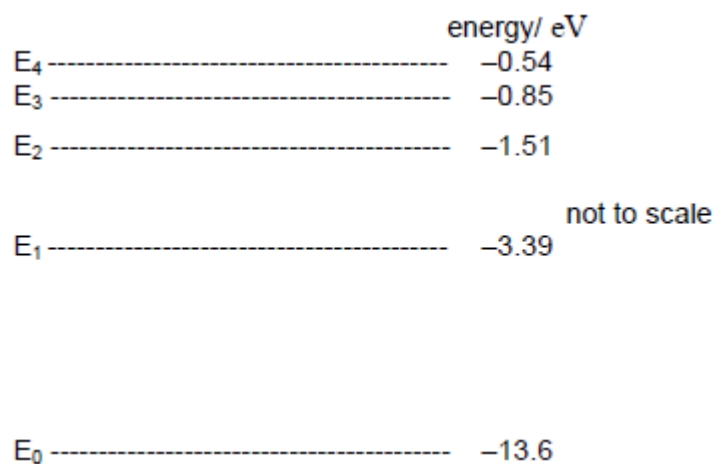
What is the frequency of the radiation emitted when an electron moves from level 2 to level 1?

- A** 2.3×10^{14} Hz ☐
- B** 3.5×10^{14} Hz ☐
- C** 4.6×10^{14} Hz ☐
- D** 8.3×10^{14} Hz ☐

(Total 1 mark)

3

The diagram gives some of the energy levels of a hydrogen atom.



The transition of an excited hydrogen atom from E_3 to E_1 causes a photon of visible light to be emitted.

Which transition causes a photon of ultraviolet light to be emitted?

A E_4 to E_3



B E_3 to E_2



C E_2 to E_1



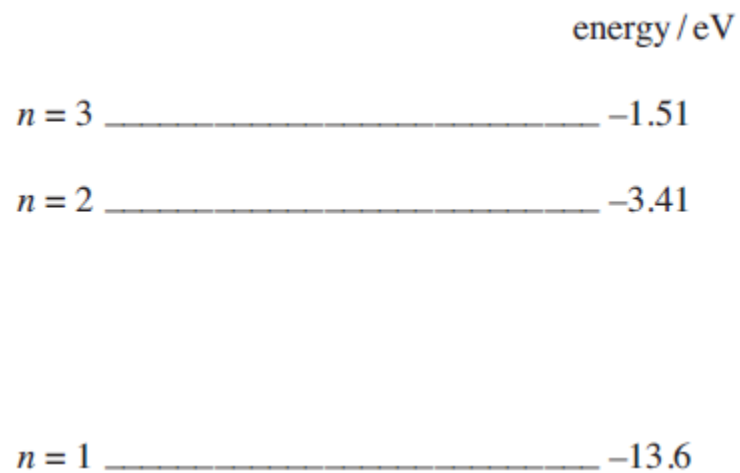
D E_1 to E_0



(Total 1 mark)

4

The diagram below shows the lowest three energy levels of a hydrogen atom.



- (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.

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

(2)

- (ii) Calculate the frequency of the photon.

frequency = _____ Hz

(3)

- (iii) The initial kinetic energy of the incident electron is $1.70 \times 10^{-18} \text{ J}$.

Calculate its kinetic energy after the collision.

kinetic energy = _____ J

(2)

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

(2)

- (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.

- (i) Explain why different frequencies are possible.

(1)

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

(2)

(Total 12 marks)

5

- (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*.

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

(1)

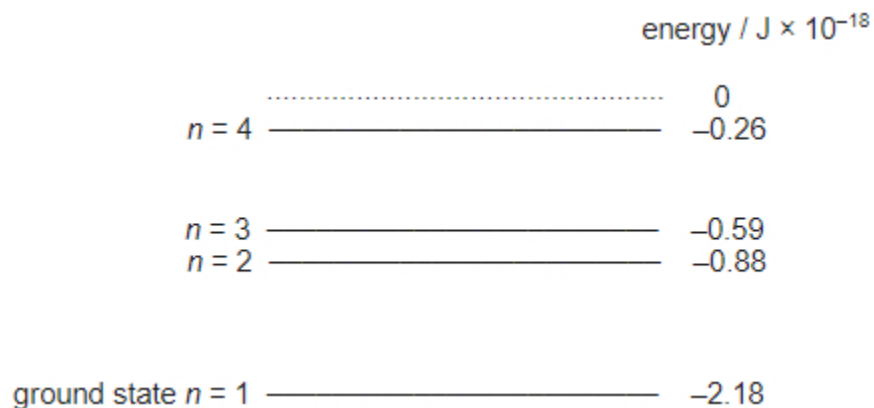
- (ii) Describe the process by which mercury atoms become excited in a fluorescent tube.

(3)

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

(3)

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



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

answer = _____ Hz

(3)

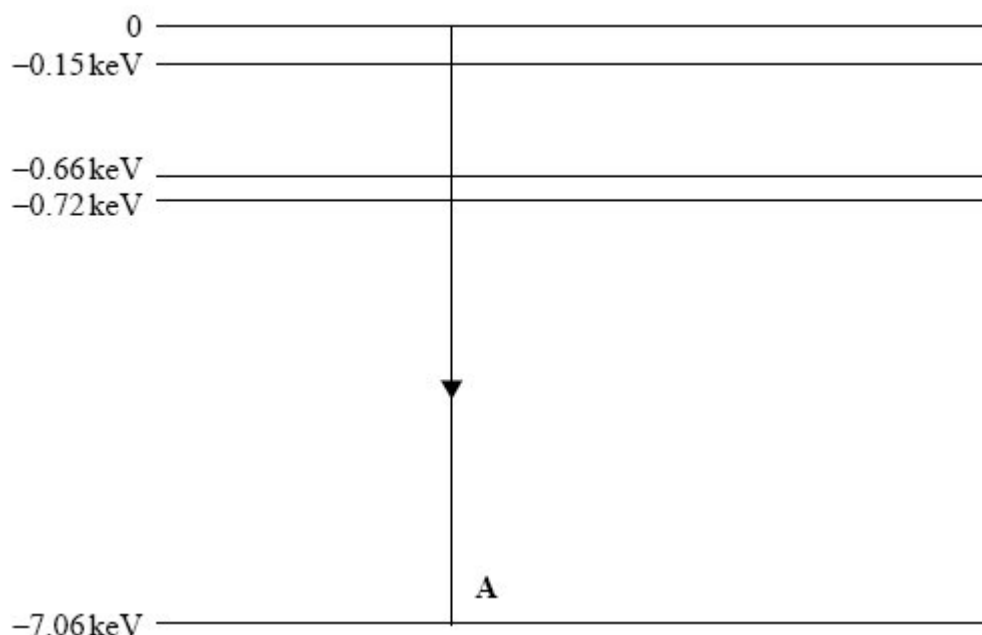
- (ii) Draw an arrow on the diagram above to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

(2)

(Total 12 marks)

6

- (a) The diagram below shows some of the energy levels for an iron atom.



- (i) Draw another arrow on the diagram above to represent the smallest energy change possible for an electron moving between two of the energy levels shown. The electron energy change selected must result in energy being emitted from the atom. Label this arrow **B**.

(1)

- (ii) In the diagram above, when the energy change labelled **A** occurs an X-ray photon is emitted. Show that the frequency of the photon is approximately 2×10^{18} Hz.

(3)

- (b) (i) Radiation of frequency 2×10^{18} Hz has a wavelength of 1.5×10^{-10} m. Calculate the speed of an electron that has a de Broglie wavelength of 1.5×10^{-10} m.

speed _____ m s⁻¹

(2)

- (ii) Explain why electrons of this wavelength would be suitable to investigate the structure of a metallic crystal.

(2)

(Total 8 marks)

7

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

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

(1)

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

(3)

- (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.

(4)

- (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)

(Total 12 marks)

8

Some energy levels of an atom of a gas are shown in **Figure 1**.

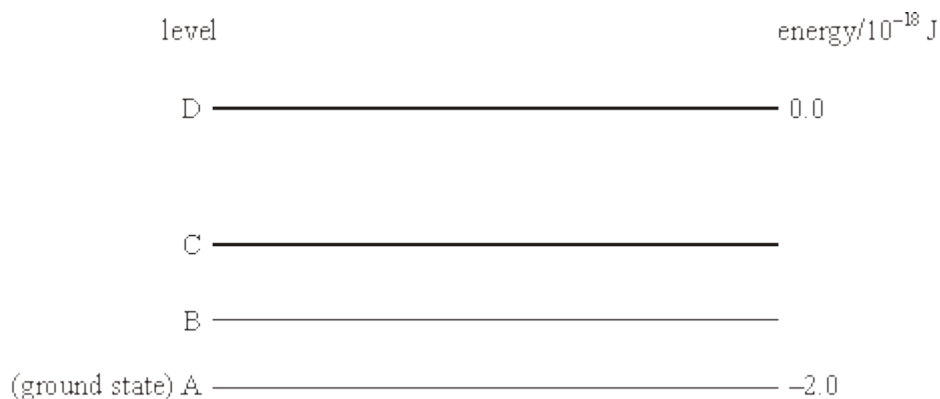


Figure 1

When a current is passed through the gas at low pressure, a line spectrum is produced. Two of these lines, which correspond to transitions from levels B and C respectively to the ground state, are shown in **Figure 2**.

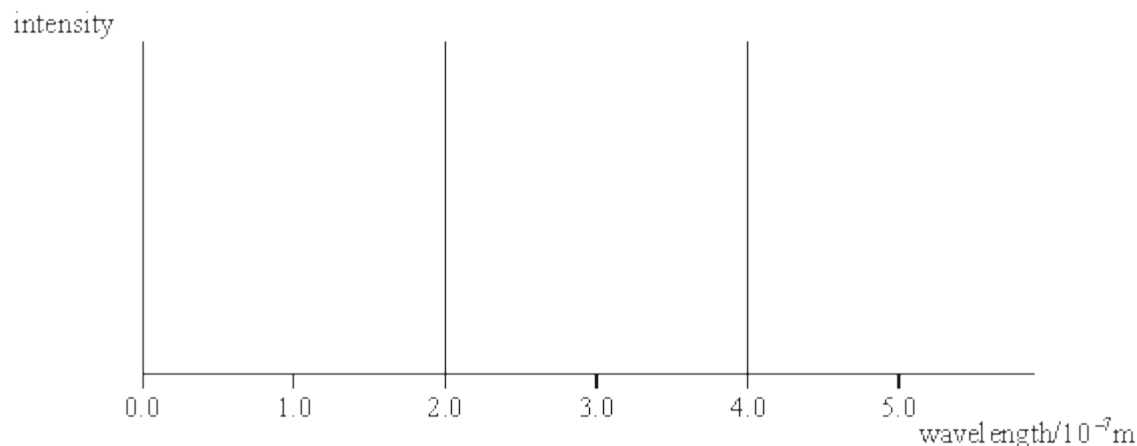


Figure 2

- (a) Describe what happens to an electron in an atom in the ground state in order for the atom to emit light of wavelength $4.0 \times 10^{-7} \text{ m}$.

You may be awarded marks for the quality of written communication in your answer.

(3)

- (b) Determine the energy, in J, of

- (i) the photons responsible for each of the two lines shown in **Figure 2**,

- (ii) levels B and C in **Figure 1**.

energy of level B = _____

energy of level C = _____

(5)

(Total 8 marks)

9

The diagram shows some of the electron energy levels of an atom.

level	energy/ 10^{-18}J
D	_____ -0.21
C	_____ -0.44
B	_____ -0.90

(ground state) A _____ -1.94

An incident electron of kinetic energy $4.1 \times 10^{-18}\text{ J}$ and speed $3.0 \times 10^6\text{ m s}^{-1}$ collides with the atom represented in the diagram and excites an electron in the atom from level B to level D.

- (a) For the incident electron, calculate

- (i) the kinetic energy in eV,

(ii) the de Broglie wavelength.

(4)

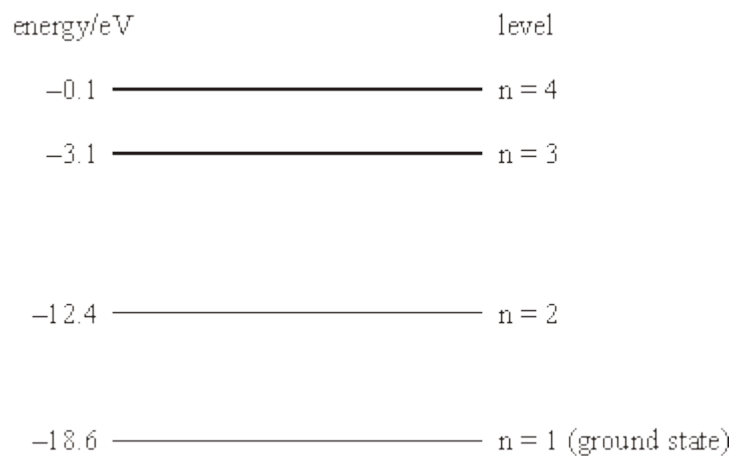
(b) When the excited electron returns directly from level D to level B it emits a photon. Calculate the wavelength of this photon.

(3)

(Total 7 marks)

10

The diagram shows some energy levels, in eV, of an atom.



Photons of specific wavelengths are emitted from these atoms when they are *excited* by collisions with electrons.

You may be awarded marks for the quality of written communication in your answer.

(a) Explain

(i) what is meant by the process of excitation,

(ii) why the emitted photons have specific wavelengths.

(5)

(b) One of the emitted photons has an energy of 9.92×10^{-19} J.

(i) Calculate the wavelength of this photon.

(ii) Determine which transition is responsible for this emitted photon.

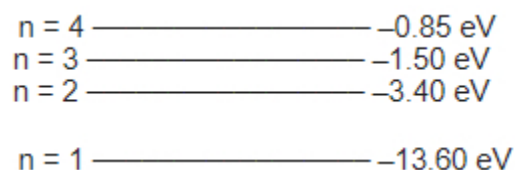
(iii) Draw an arrow on the energy level diagram above to show the transition responsible for the emission of a photon with the shortest wavelength.

(7)

(Total 12 marks)

11

The diagram below shows part of an energy level diagram for a hydrogen atom.



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

answer = _____ eV

(1)

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

- (i) On the diagram above show with arrows the transitions responsible for these photons.

(3)

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

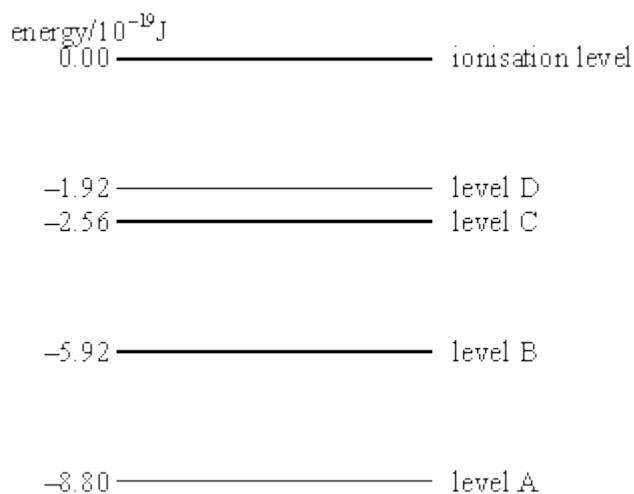
answer = _____ m

(5)

(Total 9 marks)

12

The diagram shows some of the energy levels of the mercury atom.



- (a) When electrons collide with mercury atoms, the atoms may be *excited* or may be *ionised*.

Explain what is meant by

- (i) excitation,

- (ii) ionisation.

(2)

- (b) Determine the lowest frequency of emitted radiation with reference to the energy levels in the diagram.

(2)

(Total 4 marks)

13

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

- (i) What is meant by an excited mercury atom?

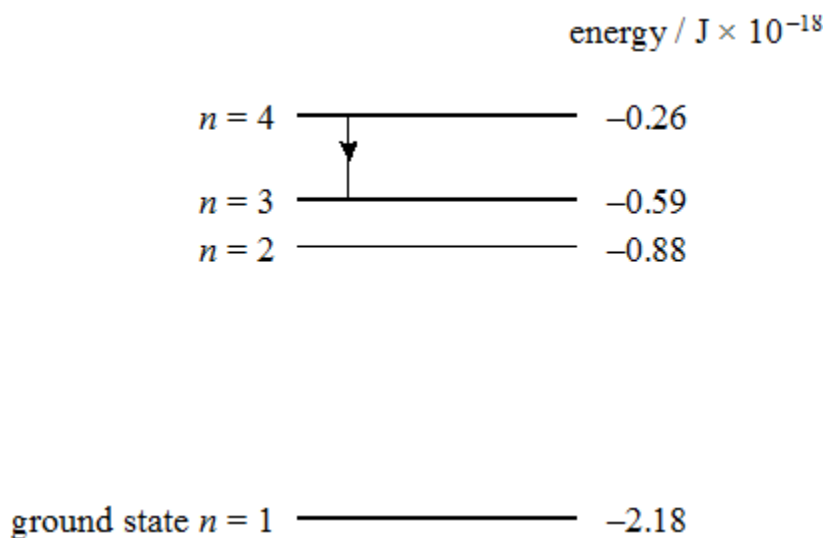
- (ii) Describe the process by which mercury atoms become excited in a fluorescent tube.

(3)

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

(2)

- (c) The lowest energy levels of a mercury atom are shown below. The diagram is **not** to scale.



- (i) Calculate the frequency of an emitted photon due to a transition, shown by an arrow, from level $n = 4$ to level $n = 3$.

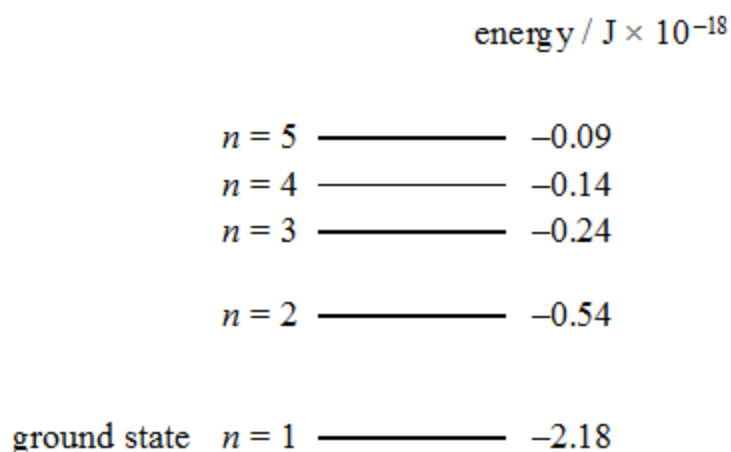
- (ii) Draw a line on the diagram to show a transition which emits a photon of a longer wavelength than that emitted in the transition from level $n = 4$ to level $n = 3$.

(3)

(Total 8 marks)

14

The lowest energy levels of a hydrogen atom are represented in the diagram below, which is **not** to scale.



- (a) Describe what happens when a hydrogen atom is ionised.

- (b) State the minimum amount of energy, in J, required to ionise a hydrogen atom from its ground state.

- (c) A hydrogen atom excited to the $n = 3$ energy level may emit either a single photon or two photons in returning to the ground state.

Describe what happens to the electron in each case.

- (d) Use the diagram above to identify the transition which produces a photon of energy $2.09 \times 10^{-18} \text{ J}$.
- (e) Calculate the frequency of an emitted photon due to a transition from level $n = 2$ to the ground state.

(Total 8 marks)

15

The diagram below shows some of the energy levels of the hydrogen atom.

energy/ 10^{-19} J

0 _____ $n = \infty$

-2.4 _____ $n = 3$

-5.4 _____ $n = 2$

-22 _____ $n = 1$ (ground state)

- (a) Explain how changes of electron energies can produce a line emission spectrum.

(3)

- (b) (i) What is meant by *ionisation*?

- (ii) State the energy, in J, required to ionise a hydrogen atom from its ground state.

- (iii) Calculate the minimum frequency of radiation that can ionise a hydrogen atom from its ground state.

- (iv) Explain what happens to an electron in the ground state of a hydrogen atom when it receives radiation of a frequency greater than the minimum frequency obtained in part (b)(iii).

(5)

- (c) Calculate the wavelength of the radiation emitted when an electron falls from level $n = 3$ to level $n = 2$ in the hydrogen atom.

(3)

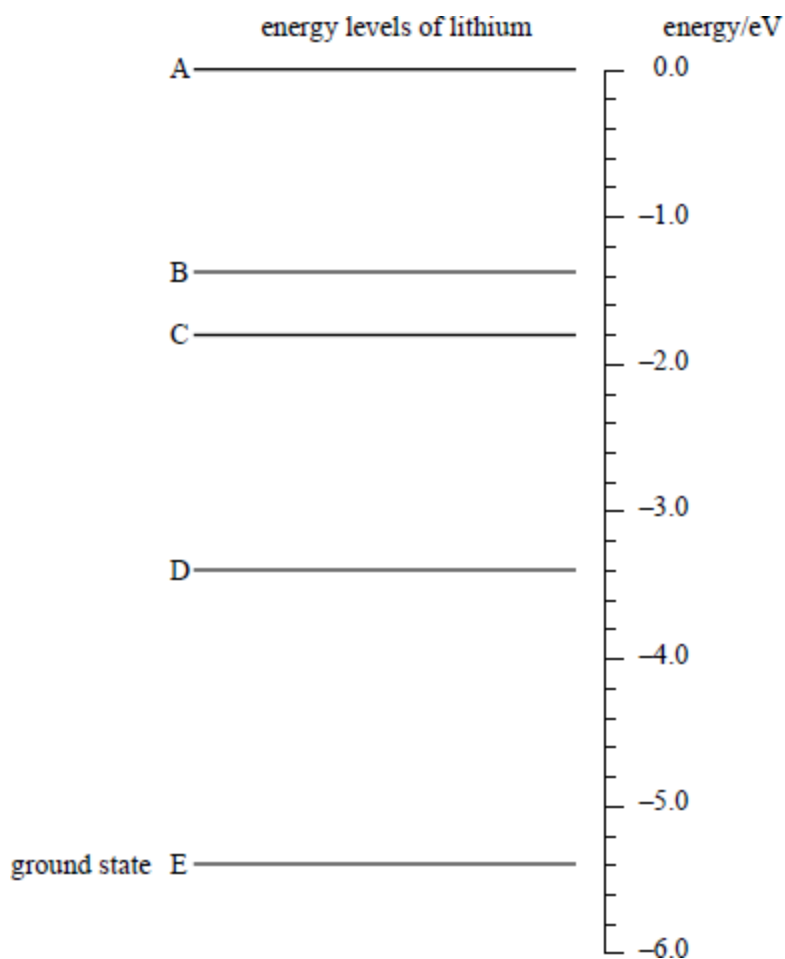
(Total 11 marks)

16

- (a) State what happens in an atom when line spectra are produced.

(2)

- (b) The diagram below represents some energy levels of the lithium atom.



- (i) Calculate the ionisation energy, in J, of the lithium atom.

- (ii) An excited lithium atom may emit radiation of wavelength 6.1×10^{-7} m.
Show that the frequency of this radiation is approximately 5.0×10^{14} Hz.

- (iii) Calculate the energy, in J, of each photon of this radiation.

- (iv) Draw, on the diagram, an arrow between two energy levels which shows the transition responsible for the emission of a photon of energy 2.0 eV.

- (v) Two transitions emit radiation of similar frequencies. One of them is the transition between A and C. What is the other?

- (vi) A transition between which two levels would give radiation of the longest possible wavelength?

(9)

(Total 11 marks)

Mark schemes

1

The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer. Guidance provided in section 3.10 of the '*Mark Scheme Instructions*' document should be used to assist in marking this question.

Level	Criteria	QoWC
L3 5–6 marks	Good discussion of both elements in question with at least 4 points mentioned in each element	The student presents relevant information coherently, employing structure, style and sp&g to render meaning clear. The text is legible.
L2 3–4 marks	Good discussion with at least 3 points in one element and 2 points in the other element	The student presents relevant information and in a way which assists the communication of meaning. The text is legible. Sp&g are sufficiently accurate not to obscure meaning.
L1 1–2 marks	Discussion of one element only incorporating at least two points.	The student presents some relevant information in a simple form. The text is usually legible. Sp&g allow meaning to be derived although errors are sometimes obstructive.
0	Unsupported combination or no relevant analysis	The student's presentation, spelling, punctuation and grammar seriously obstruct understanding.

Collisions

- *Energy from collision of charged particles transfers to electrons in gas molecules.*
- *Electrons excited to higher energy levels.*
- *The more energy the electrons absorb the higher the energy levels reached.*
- *Electrons are unstable at higher energy levels so will fall back down.*
- *When it falls down it will emit a photon.*

Formation of spectral lines

- *Photon energy = hf or photon energy proportional to frequency.*
- *Spectral lines are at specific wavelengths.*
- *Each spectral line corresponds to an electron falling down to a lower energy state.*
- *Energy gap, $\Delta E = hc/\lambda$*
- *Larger energy gap means higher energy photon is emitted so shorter wavelength or vice versa.*

Responses with no mention of photons are likely to receive zero marks.

2

C

[1]

3

D

[1]

4

- (a) (i) absorbs enough energy (from the incident) electron(by collision) OR incident electron loses energy (to orbital electron) ✓
 exact energy / 10.1(eV) needed to make the transition / move up to level 2 ✓
For second mark must imply exact energy

2

- (ii) (use of $E_2 - E_1 = hf$)
 $-3.41 - -13.6 = 10.19$ ✓
 energy of photon = $10.19 \times 1.6 \times 10^{-19} = 1.63 \times 10^{-18}$ (J) ✓
 $6.63 \times 10^{-34} \times f = 1.63 \times 10^{-18}$
 $f = 2.46 \times 10^{15}$ (Hz) ✓
(accept 2.5 but not 2.4)
CE from energy difference but not from energy conversion

3

- (iii) $E_k = 1.7 \times 10^{-18} - 1.63 \times 10^{-18}$ ✓ = 7.0×10^{-20} J ✓

2

- (iv) energy required is 12.09 eV / 1.9×10^{-18} ✓
 energy of incident electron is only 10.63 eV / energy of electron less than this (1.7×10^{-18} J) ✓
State and explain must have consistent units i.e. eV or J

2

- (b) (i) Electrons return to lower levels by different routes / cascade / not straight to ground state ✓

1

- (ii) 3 ✓
 $n=3$ to $n=1$ or $n=3$ to $n=2$ and $n=2$ to $n=1$ ✓
no CE from first mark

2

[12]

5

- (a) (i) an electron/atom is at a higher level than the ground state (1)
 or electron jumped/moved up to another/higher level

1

- (ii) electrons (or electric current) flow through the tube (1)
 and collide with orbiting/atomic electrons or mercury atoms (1)
 raising the electrons to a higher level (in the mercury atoms) (1)

3

- (iii) photons emitted from mercury atoms are in the **ultra violet** (spectrum) **or** high energy photons **(1)**

these photons are absorbed by the powder **or** powder changes frequency/wavelength **(1)**

and the powder emits photons in the visible spectrum **(1)**

incident photons have a variety of different wavelengths **(1)**

max 3

- (b) (i) (use of $E = hf$)

$$-0.26 \times 10^{-18} - 0.59 \times 10^{-18} \text{ (1)} = 6.63 \times 10^{-34} \times f \text{ (1)}$$

$$f = 0.33 \times 10^{-18} / (6.63 \times 10^{-34}) = 5.0 \times 10^{14} \text{ (Hz) (1)}$$

3

- (ii) **one** arrow between $n = 3$ and $n = 2$ **(1)** in correct direction **(1)**

2

[12]

6

- (a) (i) -0.66 to -0.72 keV line marked as **B** downward arrow

B1

- (ii) uses 7.06 (eV) (condone negative sign)

B1

attempts to multiply by 1.6×10^{-16} (condone incorrect power of 10) and to divide by 6.63×10^{-34}

B1

$$1.7(0) \times 10^{18} \text{ (Hz) cao}$$

B1

4

- (b) (i) $\lambda = h/mv$ or $\lambda = h/p$ or correct substitution

C1

$$4.4(2) \times 10^6 \text{ (m s}^{-1}\text{) [4.8(5) with } h \text{ to 2 sf]}$$

A1

- (ii) same order of magnitude as atomic spacing

B1

produces wide **diffraction** angle/good **diffraction**

B1

4

[8]

7

- (a) (i) when electrons/atoms are in their lowest/minimum energy (state) or most stable (state) they (are in their ground state) ✓

1

- (ii) in either case an electron receives (exactly the right amount of) energy ✓

excitation promotes an (orbital) electron to **a higher energy/up a level** ✓

ionisation occurs (when an electron receives enough energy) **to leave** the atom ✓

3

- (b) electrons occupy discrete energy levels ✓

and need to absorb an exact amount of/enough energy to move to a higher level ✓

photons need to have certain frequency to provide this energy or $e = hf$ ✓

energy required is the same for a particular atom or have different energy levels ✓

all energy of photon absorbed ✓

in 1 to 1 interaction or clear **a/the photon** and **an/the electrons** ✓

4

- (c) energy = $13.6 \times 1.60 \times 10^{-19} = 2.176 \times 10^{-18} \text{ (J)}$ ✓

$$hf = 2.176 \times 10^{-18} \text{ ✓}$$

$$f = 2.176 \times 10^{-18} \div 6.63 \times 10^{-34} = 3.28 \times 10^{15} \text{ Hz ✓ 3 sfs ✓}$$

4

[12]

8

- (a) an electron is excited/promoted to a higher level/orbit **(1)**
 reason for excitation: e.g. electron impact/light/energy externally applied **(1)**
 electron relaxes/de-excited/falls back emitting a photon/em radiation **(1)**
 wavelength depends on the energy change **(1)**

Max 3
QWC 1

- (b) (i) use of $E = hf$ gives) $E = \frac{hc}{\lambda}$ **(1)**

$$= \frac{6.6 \times 10^{-34} \times 3.0 \times 10^8}{4.0 \times 10^{-7}} = 5.0 \times 10^{-19} \text{ (J)} \text{ **(1)**}$$

$$(4.95 \times 10^{-19} \text{ (J)})$$

$$\text{and } \left(\frac{6.6 \times 10^{-34} \times 3.0 \times 10^8}{2.0 \times 10^{-7}} \right) = 9.9 \times 10^{-19} \text{ (J)} \text{ **(1)**}$$

- (ii) (energy of) level B = $-1.5 \times 10^{-18} \text{ (J)}$ **(1)**
 level C = $(-) 1.0 \times 10^{-18} \text{ (J)}$ **(1)**

5

[8]

9

- (a) (i) $\text{k.e.} = \frac{4.1 \times 10^{-18}}{1.6 \times 10^{-19}}$ **(1)**
 $= 26 \text{ (eV)}$ **(1)** (25.6 eV)

- (ii) (use of $\lambda_{\text{dB}} = \frac{h}{mv}$ gives) $\lambda_{\text{dB}} = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 3.0 \times 10^6}$ **(1)**
 $= 2.4 \times 10^{-10} \text{ m}$ **(1)** (2.42 $\times 10^{-10} \text{ m}$)

4

- (b) (use of $hf = E_1 - E_2$ gives) $f = \frac{(0.90 - 0.21) \times 10^{-18}}{6.6 \times 10^{-34}}$ **(1)**
 $(= 1.05 \times 10^{15} \text{ (Hz)})$

$$\text{(use of } \lambda = \frac{c}{f} \text{ gives) } \lambda = \frac{3.0 \times 10^8}{1.05 \times 10^{15}} \text{ **(1)**}$$

$$= 2.9 \times 10^{-7} \text{ m} \text{ **(1)**}$$
 (2.86 $\times 10^{-7} \text{ m}$)

3

[7]

10

- (a) (i) an electron/atom in an energy level/state or an orbiting electron **(1)**
is given energy **(1)**
to move to a higher level or orbit **(1)**
- (ii) electromagnetic radiation is emitted when an electron falls **(1)**
from one fixed level to another fixed level **(1)**
giving the photon a discrete amount of energy **(1)**

max 5
QWC 2

(b) (i) (use of $E = hf$ gives) $f = \frac{9.92 \times 10^{-19}}{6.63 \times 10^{-34}}$ **(1)** ($= 1.5 \times 10^{15}$ (Hz))

(use of $c = f\lambda$ gives) $\lambda = 1.5 \frac{3.0 \times 10^8}{1.5 \times 10^{15}}$ **(1)**

$= 2.0 \times 10^{-7}$ m **(1)**

(ii) energy (in eV) $= \frac{9.92 \times 10^{-19}}{1.60 \times 10^{-19}} = 6.2$ (eV) **(1)**

transition from $n = 2$ to $n = 1$ **(1)**

- (iii) line between $n = 4$ and $n = 1$ **(1)**
direction from 4 to 1 **(1)**

7

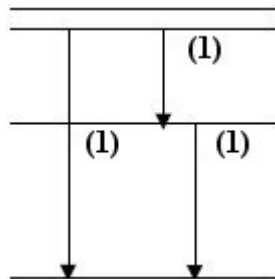
[12]

11

- (a) ionisation energy = 13.6eV **(1)**

1

- (b) (i)



- (ii) energy in Joules $= 1.90$ **(1)** $\times 1.6 \times 10^{-19} = 3.04 \times 10^{-19}$ (J) **(1)**
(use of $E = hc/\lambda$)

$3.04 \times 10^{-19} = 6.63 \times 10^{-34} \times 3 \times 10^8 / \lambda$ **(1)**
(working/equation must be shown)

$\lambda = 6.54 \times 10^{-7}$ m **(1)(1)** (2 or 3 sf for second mark)
(accept 0.65 which gives an answer of $\lambda = 1.91 \times 10^{-6}$ m)

8

[9]

12

- (a) (i) an electron moves up from one energy level to another **(1)**
 (ii) an electron is removed from an atom **(1)**

2

- (b) (use of $hf = E_2 - E_1$ gives) $f = (2.56 - 1.92) \times 10^{-19} \text{ (1)}/6.63 \times 10^{-34}$
 $= 9.65 \times 10^{13} \text{ Hz}$

(allow C.E. for incorrect ΔE)

2

[4]**13**

- (a) (i) a (mercury) atom in which an orbiting electron is raised
 to a higher (energy) level or orbit **(1)**
 (ii) by electron collision **(1)**
 with an electron accelerated by the high voltage (of the tube) **(1)**

3

- (b) the powder absorbs light / photons (emitted from the mercury) **(1)**
 powder atoms are excited and emit light / photons **(1)**
 of different wavelengths (to those received) **(1)**
 any other relevant statement such as,
 electrons cascade down energy levels, emitting many wavelengths,
 or the spectral lines are broadened **(1)**

max 2

- (c) (i) (use of $hf = E_1 - E_2$ gives) $f = \frac{-0.26 \times 10^{18} - (-0.59 \times 10^{18})}{6.63 \times 10^{-34}} \text{ (1)}$
 $= 5.0 \times 10^{14} \text{ Hz (1)}$

- (ii) line joining level $n = 3$ to level $n = 2$ with arrow pointing down **(1)**

3

[8]

14

- (a) an electron is removed from the atom **(1)**
- (b) $2.18 \times 10^{-18} \text{ (J)}$ **(1)**
- (c) (single photon): electron loses energy [or falls] from level $n = 3$ to $n = 1$
and emits a single photon **(1)**

(two photons): electron falls from level $n = 3$ to $n = 2$, emitting a photon **(1)**
followed by a fall from level $n = 2$ to $n = 1$, emitting another photon **(1)**

The Quality of Written Communication marks are awarded for the quality of answers to this question.

- (f) level $n = 5$ to the ground state [or $E_5 \rightarrow E_1$] **(1)**
- (e) (use of $hf = E_1 - E_5$ gives) $f = \frac{(-0.54 \times 10^{-18} - -2.18 \times 10^{-18})}{6.63 \times 10^{-34}}$ **(1)**
 $= 2.47 \times 10^{15} \text{ Hz}$ **(1)**

[8]**15**

- (a) need for excitation **(1)**
electrons in an atom can only exist at definite/discrete energy levels / orbits **(1)**
an electron falls from one level to another **(1)**
photon emitted **(1)**
photon has definite wavelength **(1)**

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part

(5)

- (b) (i) an electron is removed from a (neutral) atom **(1)**
- (ii) $2.2 \times 10^{-18} \text{ (J)}$ **(1)**
- (iii) ($f_{\min} = E/h$ gives) $f_{\min} = 2.2 \times 10^{-18} / 6.6(3) \times 10^{-34}$ **(1)**
(allow e.c.f from result of (b)(ii)) **(1)**
 $= 3.3(2) \times 10^{15} \text{ Hz}$ **(1)**
- (iv) ionised electron gains kinetic energy (or electron breaks free of atom) **(1)**

(5)

- (c) ($f = \frac{E_2 - E_1}{h}$ gives) $f = \frac{5.4 \times 10^{-19} - 2.4 \times 10^{-19}}{6.6(3) \times 10^{-34}}$ **(1)** ($= 4.52 \times 10^{14} \text{ Hz}$)
- ($\lambda = c/f$ gives) $\lambda = 3.0 \times 10^8 / 4.52 \times 10^{14}$ **(1)** (allow e.c.f. for f)
 $= 6.6(3) \times 10^{-7} \text{ m}$ **(1)**

(3)**[13]**

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- (a) electrons move(or excited) from one energy level(or orbit) to another **(1)**
 emitting or absorbing a definite frequency / wavelength / colour **(1)**
 or photon energy(of electromagnetic radiation) **(1)**

The Quality of Written Communication marks were awarded primarily for the quality of answers to this part

(2)

- (b) (i) $E_i = 5.2 \text{ (eV)}$ **(1)** $\times 1.6 \times 10^{-19}$
 $= 8.3 \times 10^{-19} \text{ (J)}$ **(1)**
 (allow e.c.f. if incorrect value of energy in eV)

(ii) $(f = \frac{c}{\lambda} \text{ gives}) f = \frac{3.0 \times 10^8}{6.1 \times 10^{-7}}$ **(1)**
 $= 4.9 \times 10^{14} \text{ Hz}$ **(1)**

(iii) $(\Delta E = hf \text{ gives}) E = 6.63 \times 10^{-34} \times 4.9 \times 10^{14}$ **(1)**
 $= 3.2 \times 10^{-19} \text{ (J)}$ **(1)**
 (allow e.c.f. from (ii))

- (iv) line drawn from **B** to **D** **(1)**
 (v) D to E **(1)**
 (vi) B to C **(1)**

(9)

[11]