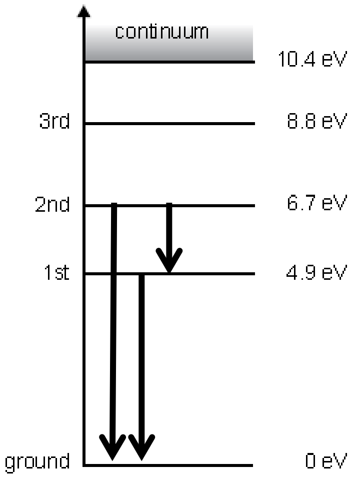
Quantised Energy Levels in Atoms

Solutions
Multiple choice questions

Example 1 2004 Question 5, 65%

The transitions marked on the graph are possible.



This gives rise to photons with energies of:
6.7 ev, 4.9 eV and 1.8 eV
∴ B, D (ANS)

Example 2 2004 Question 6, 65%

Difference between 3rd and 2nd.
∴ 8.8 – 6.7 = 2.1 eV
∴ C (ANS)

Example 3 2004 Question 11, 85%

The 'standing wave' will have four complete wavelengths. This corresponds to 8 nodes (intersections).
∴ C (ANS)

Example 4 2003 Question 1, 61%

The emission of photons occurs when the excited atom is losing energy.
∴ the arrow needs to be pointing down. The difference between the **two levels** needs to be 1.65eV
∴ A (ANS)

Example 5 1991 Question 67.

The maximum energy that the photon can have is 8.0 eV. Therefore the atom will only be excited to either the 6.7 or 4.9 state.
The emitted photon can have the energies associated with transitions between these levels and 0.
∴ 6.7 – 4.9 = 1.8
6.7 – 0 = 6.7
4.9 – 0 = 4.9.
∴ A, C, D (ANS)

Example 6 1975 Question 94, 68%

The photon must lose all its energy. Therefore, 13.6 eV is used to ionise the atom, and the remainder is the KE that the electron leaves the atom with.

$\therefore$ $KE_{electron} = 14.8 - 13.6$

$\therefore$ $KE_{electron} = 1.2$ eV

$\therefore$ **C (ANS)**

Example 7 1972 Question 106, 76%

A 15 eV photon needs to lose all its energy in one collision. This is not possible, so the photon will continue through without any interaction. Therefore the photon will emerge with 15 eV.

$\therefore$ **E (ANS)**

Example 8 1972 Question 107, 53%

A 21 eV photon needs to lose all its energy in one collision. This is not possible, so the photon will continue through without any interaction. Therefore the photon will emerge with 21 eV.

$\therefore$ **G (ANS)**

Example 9 1970 Question 103, 52%

The change in energy is 1.9 eV.
To convert to Joule, multiply by 1.6×10^{-19}.

$\therefore$ $E = 1.9 \times 1.6 \times 10^{-19}$

$\therefore$ **C (ANS)**

Short answer questions

Example 10 2012 Question 4a, 73%

Use $\Delta E = \dfrac{hc}{\lambda}$

$$\therefore 2.6 = \frac{4.14 \text{ x} 10^{-15} \times 3.0 \times 10^{8}}{\lambda}$$

$$\therefore \lambda = \frac{4.14 \text{ x} 10^{-15} \times 3.0 \times 10^{8}}{2.6}$$

$\therefore$ **λ = 478 nm (ANS)**

Example 11 2011 Question 13, 63%

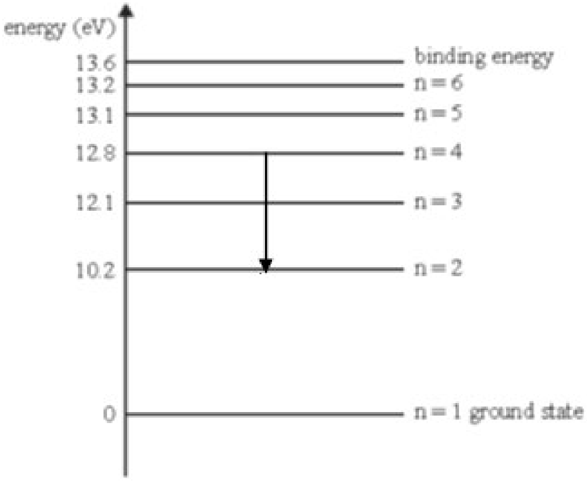
Six lines
12.8 – 0 = 12.8
12.8 – 10.2 = 2.6
12.8 – 12.1 = 0.7
12.1 – 0 = 12.1
12.1 – 10.2 = 1.9
10.1 – 0 = 10.1
∴ 12.8, 2.6, 0.7, 12.1, 1.9, 10.1 eV (ANS)

Example 12 2010 Question 11, 60%

The energy can be found from: $E = \frac{hc}{\lambda}$

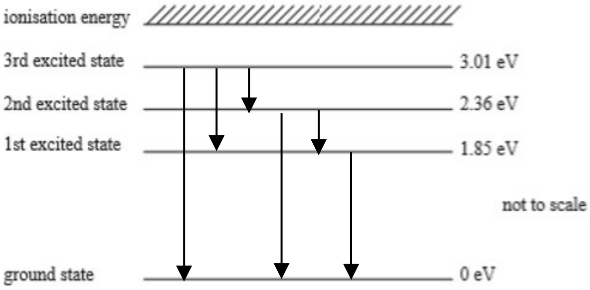
$$\therefore\ E = \frac{4.14\times10^{-15}\times3\times10^{8}}{478\times10^{-9}}$$
$= 2.598$
$= 2.6$ eV.

This is the result of a transition from 12.8 eV to 10.2 eV.



Example 13 2009 Question 10, 65%

The possible transitions are shown in the diagram below.



Example 14 2009 Question 11, 60%

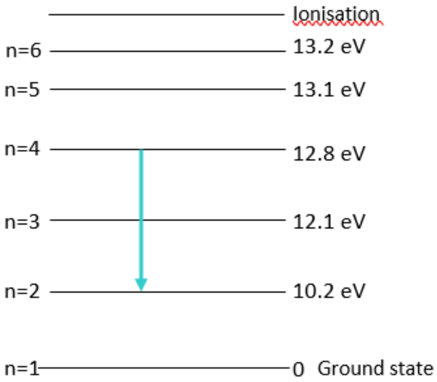
The differences between the energy levels are:
3.01 – 0 = 3.01
3.01 – 1.85 = 1.16
3.01 – 2.36 = 0.65

2.36 – 0 = 2.36
2.36 – 1.85 = 0.51

1.85 – 0 = 1.85
So the atoms can only absorb photons of these energies.
This means that the atom was initially in the first excited state (1.85 eV), and when it absorbed a 0.51 eV photons it went to the 2nd excited state (2.36 eV). When it absorbed the 1.16 eV photon it went to the 3rd excited state (3.01 eV).

Example 15 2008 Question 10, 67%

The 2.8 eV energy difference is obtained by the electron dropping from level 4 to level 2.



Example 16 2008 Question 10, 43%

Use $\lambda = \dfrac{hc}{E}$

$\therefore \lambda = \dfrac{4.14\times10^{-15}\times3\times10^{8}}{12.8}$

$\therefore$ λ = 97 nm (ANS)

Example 17 2007 Question 7, 50%

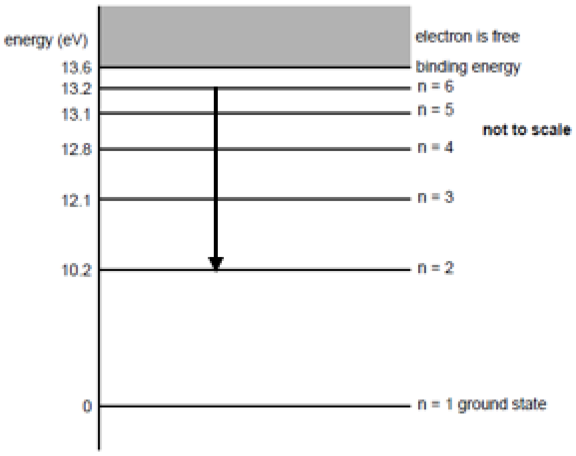
Use $E = \dfrac{hc}{\lambda}$

$= \dfrac{4.1\times10^{-15}\times3\times10^{8}}{434.1\times10^{-9}}$

= 2.86 eV (ANS)

Example 18 2007 Question 8 50%

The energy difference is 3.0 eV, when a photon is emitted, the atom loses energy, so the arrow represents a downward transition.



Example 19 2007 Question 9, 50%

Light from the sun is absorbed by molecules in the atmosphere. Not all frequencies are absorbed, only the frequencies that correspond to the difference between any two energy levels of the atoms. This absorbed light is re-emitted from the atom, but in a random direction.
Thus the light reaching the earth will have a reduced amount of those absorbed frequencies and dark lines appear in the spectrum of light from the sun.
The dark lines exist because photons are absorbed which correspond to the energy levels in hydrogen. This indicates the presence of hydrogen in the atmosphere.

Example 20 2006 Question 5, 59%

Use E = hf.
Therefore the highest frequency will occur when the change in energy is greatest. If the atom is in n= 4 state, then the largest amount of energy that it can lose is 3.61 eV.

$$\therefore f = \frac{E}{h}$$

$$\therefore f = \frac{3.61}{4.14 \times 10^{-15}}$$

$$\therefore \mathbf{f = 8.7 \times 10^{14}\ Hz\ (ANS)}$$

Example 21 2006 Question 5, 59%

Electrons have a de Bröglie wavelength.
When the atom has stable energy levels, these electrons only exist in states where a ‘standing wave’ is formed around the nucleus – orbits. This only allows specific orbits, as they need to be multiples of the de Bröglie wavelengths.

Example 22 2005 Question 9,

The lowest energy photon is associated with the smallest gap between the energy levels.

$$\therefore \mathbf{5.2 - 3.4 = 1.8\ eV\ (ANS)}$$

Example 23 2003 Question 2, 50%

The first excited state is at 2.10 eV

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

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

$$= \frac{4.1 \times 10^{-15} \times 3 \times 10^{8}}{2.1}$$

$$\mathbf{= 5.86 \times 10^{-7} m \ (ANS)}$$

Example 24 1999 Question 7, 51%

When the mercury atoms go from
n = 3 to n = 1 level then the photon given off must have an energy of
–3.7- -10.4 eV.= 6.7 eV

$$\text{Since } E = \frac{hc}{\lambda} \ \therefore \quad \lambda = \frac{hc}{E}$$

$$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{6.7}$$

$$\mathbf{= 1.85 \times 10^{-7} \ m \ (ANS)}$$

Example 25 1997 Question 5, 52%

The photons that are emitted from an excited atom are the result of the atom changing its level of excitement. When the neon atoms are in the fifth excited state, they are capable of dropping to the second excited state.
This would mean a change of energy of 20.7 – 18.7 = 2.0 eV.
To lose this energy, the neon atoms need to give off a photon of energy 2 eV.

Example 26 1996 Question 5, 36%

When the mercury atoms go from n = 2 to
n = 1 level then the photon given off must have an energy of 4.9 eV

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

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

$$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{4.9}$$

$$\mathbf{= 2.5 \times 10^{-7} \ m \ (ANS)}$$

Alternatively, using the data that was supplied on the exam, we get

$$\therefore \lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{4.9 \times 1.6 \times 10^{-19}}$$

$$\mathbf{= 2.5 \times 10^{-7} \ m \ (ANS)}$$

Example 27 1996 Question 6, 60%

Using $p = \frac{h}{\lambda}$, we get

$$p = \frac{6.6 \times 10^{-34}}{2.5 \times 10^{-7}}$$

$$\therefore \mathbf{p = 2.6 \times 10^{-27} \ N \ s \ (ANS)}$$

Example 28 1994 Question 3

The excited neon atoms lose energy by emitting photons. The energy emitted needs to be the difference between two energy levels.
When the atom transitions from 4.30×10^{-18} to 3.97×10^{-18} it emits a photon of

3.3×10^{-19} J (ANS)