Checkpoints Chapter 20

Energy Levels of Atoms

Multiple Choice questions

Question 1

If 1eV = 1.6×10^{-19}J
$\therefore$ 2.6 keV = $2.6 \times 10^{3} \times 1.6 \times 10^{-19}$
= 4.2×10^{-16}
$\therefore$ 4.2×10^{-16}J (ANS)

Question 2

To be able to absorb the photon the atom has to be able to accept all the energy of the photon as it moves from one energy level to another. If the atom is in the 0.4 keV state, it can only absorb a photon to take it to either 2.6 or 20 keV.
It could absorb a 2.2 keV or a 19.6 keV photon, and be in an allowable state.
$\therefore$ B, D (ANS)
This answer is different to the one in the back of the book.

Question 3

For the atom to return to its ground state, (its preferred option), then it needs to give of photons as it loses energy. We don't know what the values of the energies are, so the photons will have the energy corresponding to the difference between two different energy levels.

Eg. $E_3 - E_2$, $E_3 - E_1$, $E_3 - E_0$,
$E_2 - E_1$, $E_2 - E_0$, $E_1 - E_0$.

$\therefore$ B (ANS)

Question 4

Since the ground state is –13.6 eV, then an atom excited to the –1.50 eV level can return to ground state in a variety of ways.
-1.50 → -13.6
-1.50 → -3.40 → -13.6.

These paths would cause the emission of photons with energies of -1.50 → -13.6 = 12.1 eV
-1.50 → -3.40 = 1.9 eV
-3.40 → -13.6 = 10.2 eV
$\therefore$ B (ANS)

Question 5

A
Is possible if the atom goes from
–0.85 → -3.40 → -13.6
B
Is possible if the atom goes from
–0.85 → -1.50 → -3.40
C
Is possible if the atom goes from
–0.85 → -1.50 → -13.6

$\therefore$ D is not possible, because if the atom emitted a 12.75 eV photon it would then be in the ground state. It can't then emit another photon.
$\therefore$ D (ANS)

Question 6

The atom needs to absorb all the energy of the photon. So the photon energy needs to be equal to the difference between the ground state and one of the energy levels.

From this chart Hydrogen can absorb photons of energy 12.75 eV, 12.1 eV, 10.2 eV.
$\therefore$ A = 10.2 eV.
The photon would excite the atom to the –3.4 eV state.
$\therefore$ A (ANS)

Question 7

Use $2\pi r = n\lambda$, therefore

$\therefore \lambda = \frac{2\pi r}{n}$, where n is an integer.

If n = 4.
$\therefore$ A (ANS)

Question 8

For the electron to be in a stable orbit, it needs to be a standing wave, where the circumference of the orbit wavelength is a multiple number of wavelengths.
$\therefore$ A (ANS)

Question 9 **(2017 Q17, 1m, 59%)**

De Bröglie suggested that electrons have wave properties such as wavelength, and that the orbits (energy levels) that could exist were those where the wavelength of the electron set up a stable standing wave.

∴ D **(ANS)**

Extended questions

Question 10

It will be able to absorb photons to take it to another energy level. If you assume that E_3 is higher than the possible photon energies are $E_3 - E_1$, and $E_2 - E_1$.

∴ $E_3 - E_1$, and $E_2 - E_1$ **(ANS)**

Question 11

The neon atom was at its lowest state, 1.07×10^{-18}
Then to get to either of the other two states its energy needs to increase by

$4.30 \times 10^{-18} - 1.07 \times 10^{-18} = 3.23 \times 10^{-18}$J

$3.97 \times 10^{-18} - 1.07 \times 10^{-18} = 2.90 \times 10^{-18}$J

This will correspond to photon frequencies of
E = hf

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

$$= \frac{3.23 \times 10^{-18}}{6.63 \times 10^{-34}}$$

$= 4.87 \times 10^{15}$ Hz

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

$$= \frac{2.90 \times 10^{-18}}{6.63 \times 10^{-34}}$$

$= 4.37 \times 10^{15}$ Hz

4.87×10^{15} Hz, 4.37×10^{15} Hz **(ANS)**

These answers are different to those in the back of the book.

Question 12

An orbit of radius 100 pm will have a circumference of 628 pm, which is twice the wavelength. This will allow for a standing wave pattern.

∴ Yes **(ANS)**

Question 13

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

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

$$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{5.9}$$

∴ 2.11×10^{-7} m **(ANS)**

Question 13a **(2014 Q23a, 2m, 60%)**

$$\text{Use } \lambda = \frac{h}{p} = \frac{h}{mv}$$

$$\therefore \lambda = \frac{6.63 \times 10^{-34}}{9.1 \times 10^{-31} \times 2 \times 10^{6}}$$

$\therefore \lambda = 3.64 \times 10^{-10}$

∴ λ = 0.36 nm **(ANS)**

Question 14 **(2014 Q23b, 3m, 37%)**

Electrons orbiting a nucleus can be modelled as circular standing waves, therefore the electron is exhibiting wave like properties.
The standing wave will exist only if the circumference of its orbit corresponds to a whole number of wavelengths.
i.e. $2\pi r = n\lambda$.
Therefore only specific values of wavelength are permitted. The momentum of the electron is related to its wavelength, and the energy of the electron is related to its momentum. Therefore the electron's energy is quantised.

Question 15a **(2012 Q4a, 2m, 75%)**

The gain in energy is 12.8 – 10.2
= 2.6 eV

$$\text{Use } \Delta E = \frac{hc}{\lambda}$$

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

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

∴ λ = 478 nm **(ANS)**

Question 15b (2012 Q4b, 3m, 40%)

Electrons exhibit wavelike properties. As they orbit the nucleus they must form standing waves. This means that only whole numbers of wavelengths can exist. i.e the wavelength is quantised.
The energy of the electron is related to its wavelength, hence energies are quantised.
The standing wave will exist only if the circumference of its orbit corresponds to a whole number of wavelengths. i.e. $2\pi r = n\lambda$,

where $\lambda = \frac{h}{mv}$

Question 16a (2013 Q20a, 2m, 40%)

Using $\Delta E = \frac{hc}{\lambda}$, the longest wavelength implies the smallest energy transition. The smallest energy transition is from 3.19 to 2.11 eV. (When the atom is in the 3.19 eV state).
$\therefore$ 3.19 – 2.11 = 1.08 eV

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

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

$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{1.08}$

$\therefore$ **λ = 1.15 × 10^{-6} m (ANS)**

Question 16b (2013 Q20b, 3m, 44%)

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

$\therefore \Delta E = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{588.63 \times 10^{-9}}$

$\therefore \Delta E = 2.11$ eV
This corresponds to the transition from n= 2 (first excited state) to n = 1 (ground state).

Question 17 (2015 Q19a, 4m, 65%)

The transition from n = 3 to n = 1, will result in the largest energy change, hence the greatest frequency.
Use E = hf
$\therefore E = 4.14 \times 10^{-15} \times 2.63 \times 10^{16}$
$\therefore$ E = 108.9 eV

The transition from n = 2 to n = 1, will produce a frequency of 2.22×10^{16} Hz.
Use E = hf
$\therefore E = 4.14 \times 10^{-15} \times 2.22 \times 10^{16}$
$\therefore$ E = 91.9 eV
$\therefore$ n = 2: 91.9 eV
$\therefore$ n = 3: 108.9 eV (ANS)

The transition from n = 3 to n = 2, will produce a frequency of 0.41×10^{16} Hz.
Use E = hf
$\therefore E = 4.14 \times 10^{-15} \times 0.41 \times 10^{16}$
$\therefore$ E = 17.0 eV
This answer is different to the back of the book.

Question 18a (2014 Q22a, 2m, 40%)

If the atom is in the first excited state it has an energy value of 4.9 eV. It can absorb a 1.8 eV photon as this will raise it to the 6.7 eV energy level.
If the atom was in its first excited state, at 4.9 eV, the only photon that it can emit will be one of 4.9 eV. There is no energy level 1.8 eV lower than the first excited state.
Therefore it can absorb a 1.8 eV photon, but not emit one.

Question 18b (2014 Q22b, 3m, 40%)

The energy of the photons emitted from the excited mercury atom can be:
10.4 – 9.8 = 0.6 eV
10.4 – x,
9.8 – x
9.8 – 6.7 = 3.1 eV
x – 6.7,
and 6.7 – 4.9 = 1.8 eV.

The missing values are either 0.9, 1.5 or 2.2 eV.
10.4 – x will be 0.6 larger than 9.8 – x.
$\therefore$ 10.4 – x = 1.5 and 9.8 – x = 0.9
$\therefore$ x = 8.9 eV.
$\therefore$ x – 6.7 – 8.9 – 6.7 = 2.2 eV.
$\therefore$ 8.9 eV (ANS)

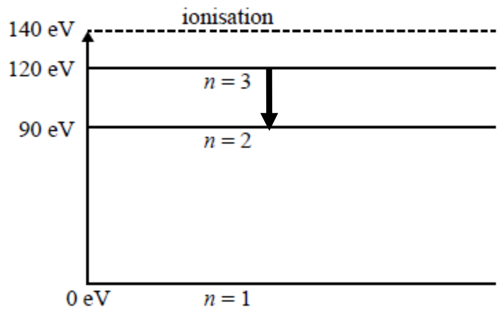
Question 19a (2015 Q19b, 2m, 65%)

Use E = hf

$\therefore E = 4.14 \times 10^{-15} \times 7.25 \times 10^{15}$

$\therefore E = 30$ eV

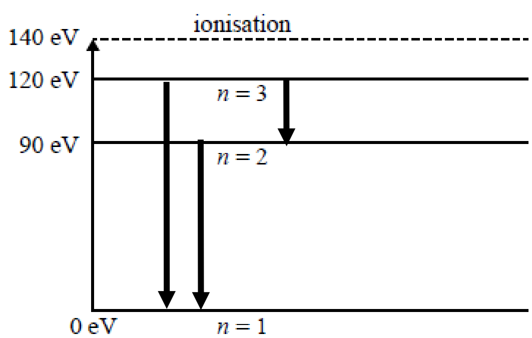
This relates to the transition from 120 – 90 eV.



∴ From n = 3 to n = 2 (ANS)

Question 19b

There are three transitions between the levels.



∴ 3 photons (ANS)

Question 20a (2016 Q21a, 2m, 61%)

For a photon, $E = \frac{hc}{\lambda}$

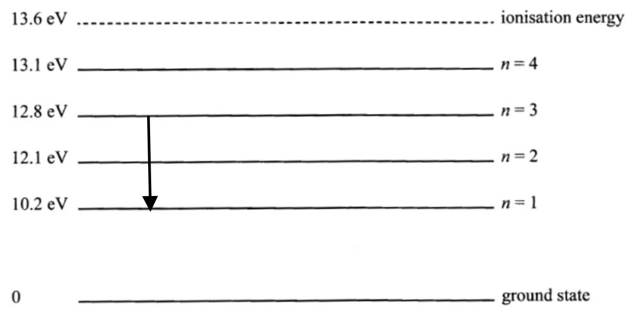
$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{2.6}$

$\therefore \lambda = 4.78 \times 10^{-7}$

∴ λ = 478 nm (ANS)

Question 20b (2016 Q21b, 2m, 67%)

The transition needs to be 2.6 eV. Therefore it goes from 12.8 down to 10.2.

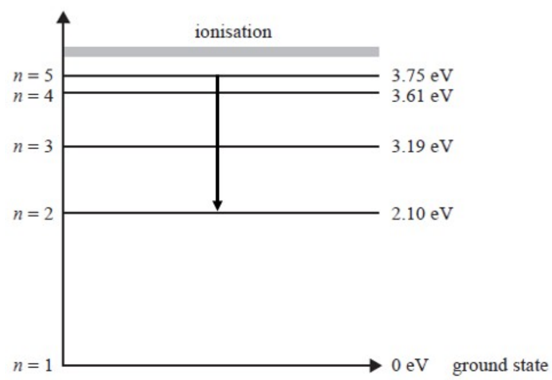


Question 20c (2016 Q21c, 3m, 63%)

The photon energies are the transitions from 12.8 etc to ground.

∴ 12.8, 12.1, 10.2, 2.6, 1.9, 0.7 eV (ANS)

Question 21a (2017 Q18a, 1m, 73%)



Question 21b (2017 Q18b, 2m, 49%)

The n = 5 to ground state transition is 3.75 eV

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

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

$\therefore \lambda = \frac{4.14 \times 10^{-15} \times 3 \times 10^{8}}{3.75}$

$\therefore \lambda = 3.312 \times 10^{-7}$ m

∴ λ = 331 nm (ANS)

Question 21c (2017 Q18c, 2m, 25%)

For a spectral line of 2.5 eV to exist, Their needs to be a transition from one level to another with a difference of 2.5 eV. There isn't one, so a photon of 2.5 eV won't be observed.
