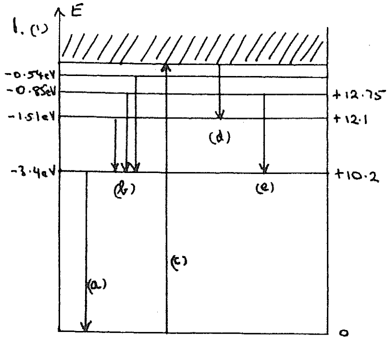
1. (1)



(2) $\lambda_{max} \equiv f_{min} \equiv E_{min}$

$E_{min} = 1.9\text{eV}$

$= 1.9 \times 1.6 \times 10^{-19}\text{J}$

$= \underline{3.04 \times 10^{-19}\text{J}}$

$\therefore hf = \frac{hc}{\lambda} = 3.04 \times 10^{-19}\text{J}$

$\therefore \lambda = \frac{hc}{3.04 \times 10^{-19}}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{3.04 \times 10^{-19}}$

$\lambda_{min} = \underline{\underline{6.54 \times 10^{-7}\text{m}}}$

This belongs to visible part of the e/m spectrum (red light)

<u>Series Limit.</u> λ_L

$E = 3.4$ eV.

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

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

ie $\lambda \propto \frac{1}{E}$.

$\therefore \lambda_L = \frac{1.9}{3.4} \times \lambda_{red}$

$= \frac{1.9}{3.4} \times 6.54 \times 10^{-7}$

$= \underline{\underline{3.66 \times 10^{-7}\text{m}}}$

This belongs to the ultra-violet part of the e/m spectrum

2. (1)

A: 10eV
B: 12eV
C: 12.8eV
D: 1.9eV

(2) $E = 1.9\text{eV} = 3.04 \times 10^{-19}\text{J}$.

$\therefore hf = 3.04 \times 10^{-19}$

$f = \frac{3.04 \times 10^{-19}}{6.63 \times 10^{-34}}$

$= \underline{\underline{4.59 \times 10^{14}\text{ Hz}}}$

$\lambda = 6.54 \times 10^{-7}\text{m}$ (see 1(2))

This belongs to the Balmer series.

3. (1) $E_1 = 3.61 - 3.19 = 0.42\text{eV}$.

$E_2 = 3.19 - 2.10 = 1.09\text{eV}$

$E_3 = 3.61 - 2.10 = 1.59\text{eV}$

$hf = h\frac{c}{\lambda} = E$

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

$\therefore \lambda_1 = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{0.42 \times 1.6 \times 10^{-19}}$

$= \underline{\underline{2.96 \times 10^{-6}\text{m}}}$

$\lambda \propto \frac{1}{E}$

$\therefore \frac{\lambda_2}{\lambda_1} = \frac{E_1}{E_2}$

$\therefore \lambda_2 = \frac{E_1}{E_2} \times \lambda_1$

$= \frac{0.42}{1.09} \times 2.96 \times 10^{-6}$

$= \underline{\underline{1.14 \times 10^{-6}\text{m}}}$

$\lambda_3 = \frac{0.42}{1.59} \times 2.96 \times 10^{-6}$

$= \underline{\underline{7.82 \times 10^{-7}\text{m}}}$

(2)(a) Atoms may be raised to 1st or 2nd excited states.

∴ Emitted photons will have energy 3.19eV, 2.10eV, 1.09eV.

(b) Scattered electrons will have energies of:

<u>3.60eV, 1.50eV, 0.41eV</u>

4. The single electron of hydrogen may be raised to any one of a large number of higher energy excited states. As these excited electrons revert to the ground state a large no. of different energy transitions are possible, giving rise to a large number of spectral lines. It is the number of possible energy states that determines the no. of lines – not the number of electrons.

5 (1) $E_4 \to E_0$, $E_4 \to E_1$, $E_4 \to E_2$, $E_4 \to E_3$

$E_3 \to E_0$, $E_3 \to E_1$, $E_3 \to E_2$

$E_2 \to E_0$, $E_2 \to E_1$

$E_1 \to E_0$

[E_n = n'th excited state
E_0 = ground state]

∴ 10 transitions are possible

∴ 10 different photons could be emitted.

(2) $\lambda_{max} \equiv f_{min} \equiv E_{min} = 0.31\text{eV}$

$[E_4 \to E_3]$

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

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

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{0.31 \times 1.6 \times 10^{-19}}$

$\underline{\underline{\lambda_{max} = 4.01 \times 10^{-6}\text{m}}}$

$\lambda_{min} \equiv f_{max} \equiv E_{max} = 13.06\text{eV}$

$[E_4 \to E_0]$

$\therefore \lambda_{min} = \frac{hc}{E}$

$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{13.06 \times 1.6 \times 10^{-19}}$

$= \underline{\underline{9.52 \times 10^{-8}\text{m}}}$

6 (1) Ionisation energy = <u>10.4eV</u>

(2) $E_3 \to E_2$: $\Delta E = 1.8\text{eV}$

(3) Assuming mercury atoms are in the ground state, photons removed will be 4.9eV, 6.7eV, 8.8eV.

(4) fluorescence is the conversion of high energy photons (absorbed) by atoms into low energy photons, then re-emitted by the atoms. Referring to the diagram, if an 8.8eV photon is incident on the mercury atom it can be absorbed by the atom which is raised to the 3rd excited energy state. When the atom reverts to the ground state, it may do so directly emitting a photon of energy 8.8eV, or it may do so in stages emitting a subset of the following photons.

2.1eV, 3.9eV, 4.9eV, 1.8eV, 6.7eV

(5) See above

7. As the energy level of the hydrogen atom increases, the difference in energy between energy levels decreases. The Paschen series of lines consists of all transitions that end in the 2nd excited state. The maximum possible energy of such a transition is 0.85eV (this is the series limit). The Balmer series of lines consists of all transitions that finish in the 1st excited state. The minimum energy of such a transition is 1.9eV & the maximum is 3.4eV. The Balmer series consists of 4 lines in visible & the rest in the UV part of the spectrum. The Paschen lines are all of less energy than the Balmer, and are all in the infrared region of spectrum.

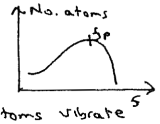
8. Continuous range of frequencies is emitted by vibrating atoms/molecules (ie charges) which emit e/m radiation of the same frequency as the frequ. of oscillation of the charge.

Typically, continuous range of frequencies is emitted by solids and liquids.

In a gas (vapour), the atoms are not vibrating. They are moving in straight lines, colliding with each other & with the sides of the container.
When these atoms are excited, (eg by heating), they can be raised to higher energy states.
They emit their radiation when the atom reverts to a lower energy state, losing energy and emitting a photon of energy equal to the energy difference between the states.

Because only a finite set of discrete energy states exist, there can only be a discrete set of transition ∴ a discrete set of frequencies.

9. Atoms (charges) in filament are vibrating with a continuous range of frequencies



As temperature increases, the graph moves to right as atoms vibrate with higher range of frequencies.
As filament globe heats up the frequencies of vibration increase & so the e/m emission frequency increases and waves move from infra red → red (glows red hot)
As temp. increases further the filament is eventually emitting waves from Red → Violet.
ie it glows white hot.

10. 200 W globe is hotter than a 25 W globe.
∴ In 200 W globe atoms are vibrating with frequencies in a higher range.
∴ 200 W globe has a greater proportion of B-V end of visible spectrum than 25 W.
∴ It appears "whiter".

$\boxed{\text{A 25 W globe appears yellow when compared with 200 W}}$

11. The line emission spectrum is a set of bright coloured lines on a dark background.
The line absorption spectrum is a continuous spectrum of white light (ROYGBIV) with dark lines on this coloured background.
The position (frequency) of the dark lines in the absorption spectrum is the same as the position of the bright lines in the emission spectrum.

12. Absorption lines are caused by photons being absorbed by the atoms of an element the atom is raised to a higher energy state.
The energy of the absorbed photon must be exactly the same as the energy difference between the 2 states.
Balmer absorption lines would mean that the atom was being raised from the 1st excited state to a higher state.
But at room temperature the atoms are not in the 1st excited state — all atoms are in the ground state
∴ No Balmer absorption lines are observed at room temp

13. In a spectroscope we are actually observing reinforcement images of the slit through which light enters the apparatus.
A fine slit ∴ appears as a <u>fine</u> rectangle
ie a "line".

14.

$$\lambda_1 = 259\,nm$$
$$= \underline{2.59\times10^{-7}}\,m$$
$$f_1 = \frac{c}{\lambda_1} = \frac{3.0\times10^{8}}{2.59\times10^{-7}}$$
$$= \underline{1.16\times10^{15}}\,Hz$$
$$f \propto \frac{1}{\lambda}$$
$$\therefore \frac{f_2}{f_1} = \frac{\lambda_1}{\lambda_2} \quad \text{ie } f_2 = \frac{\lambda_1}{\lambda_2}\times f_1$$
$$\lambda_2 = 254\,nm$$
$$\therefore f_2 = \frac{259}{254}\times 1.16\times10^{15}$$
$$= \underline{1.18\times10^{15}\,Hz}$$
$$\lambda_3 = 251\,nm$$
$$\therefore f_3 = \frac{259}{251}\times 1.16\times10^{15}$$
$$= \underline{2.00\times10^{15}}\,Hz$$

15. If an atom is in a meta-stable excited state, it can be stimulated to revert to a lower energy state if a photon, of energy equal to the energy difference between the 2 states, is incident on it.
When the atom "drops" to the lower energy state it emits a photon with the same frequency, direction of travel and phase as the initial incident photon.
For stimulated emission to occur the atom must have a meta-stable state, for the electron must be in the excited state to be stimulated by the photon.

16. Population inversion occurs when there are more atom, in a sample of material, in an excited state than the ground state.
For this to occur the atom must have a meta-stable excited state.
If it did not, then when individual atoms are excited they immediately revert to the ground state
∴ Population inversion could not occur.

17. (1) The higher state is meta-stable.

(2) $E_{photon} = 1.96\,eV$

(3) Zero.
Stimulated emission ⇒ photons are emitted with the same phase as the stimulating photon.

(4)

$$hf = \frac{hc}{\lambda} = E$$
$$\therefore \lambda = \frac{hc}{E}$$
$$= \frac{6.63\times10^{-34}\times3\times10^{8}}{1.96\times1.6\times10^{-19}}$$
$$= \underline{6.34\times10^{-7}\,m}$$

This is RED light.