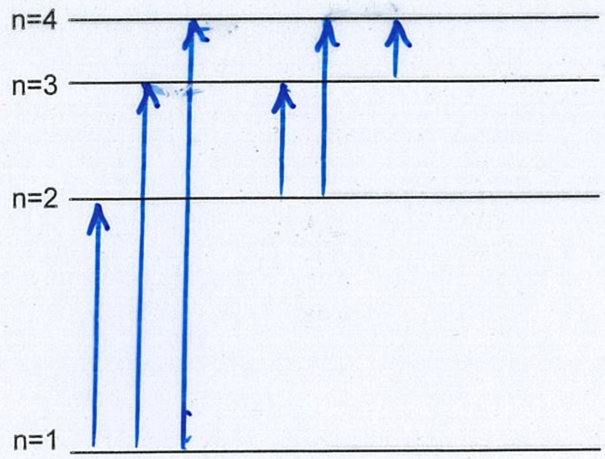
Assessor's use only

QUESTION TWO: SPECTRUM FROM STARS

Stars usually emit a continuous range of wavelengths of light from their surface. However, stars are surrounded by clouds of gas containing hydrogen which absorb some colours.

(a) The diagram below shows of some of the energy levels for hydrogen gas. Draw arrows on the diagram showing **all** possible transitions resulting from the **absorption** of light.



A/ correct answer but with arrows the wrong way
M/ all correct

AM,

(b) Use the Bohr model of the hydrogen atom to explain why only some **specific** colours of light are absorbed by the gas.

The Bohr model of the hydrogen atom states that electrons can exist only in particular energy levels/shells. When photons of light are shone onto an atom, the atom can only absorb that photon if the energy corresponds exactly to a transition between electron energy levels, making the electron jump up to a higher level. As a result, only photons of specific frequencies can be absorbed, and all other colours pass through the gas.

AME,

A/ one correct relevant statement
M/ Link made between discrete energy levels and discrete energy jumps OR Link made between photon energy and discrete energy jumps.
E/ ... AND ...

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A star surrounded by a cloud of hydrogen gas has an absorption line at the infra red frequency of 2.34×10^{14} Hz. This line is due to atoms in the n = 3 state absorbing a photon.

(c) Calculate the final state (n) of the atom, after it absorbs this photon.

$E_{final} = E_3 + E_\gamma$, $E_\gamma = hf$

$E_\gamma = (6.63 \times 10^{-34})(2.34 \times 10^{14}\,Hz)$

$E_\gamma = 1.55142 \times 10^{-19}\,J$ A/ correct value OR

$E_3 = -\frac{hcR}{3^2} = \frac{-(6.63 \times 10^{-34})(3.00 \times 10^{8}) \times (1.097 \times 10^{7})}{9}$

$E_3 = -2.42437 \times 10^{-19}\,J$ A/ correct value OR

$E_{final} = (-2.42437 \times 10^{-19}) + (1.55142 \times 10^{-19})$

$= -0.87295 \times 10^{-19}\,J$

$E_{final} = -\frac{hcR}{n_{final}^2} \Rightarrow n_{final} = \sqrt{\frac{-hcR}{E_{final}}}$

$= \sqrt{\frac{-(6.63 \times 10^{-34})(3.00 \times 10^{8})(1.097 \times 10^{7})}{-(0.87295 \times 10^{-19}\,J)}}$

$= 4.9995$ i.e. $n_{final} = 5$ (must be whole number)

E/ value correct

OR

$v = f\lambda \Rightarrow \lambda = v/f$

$\lambda = \frac{(3.00 \times 10^{8}\,ms^{-1})}{(2.34 \times 10^{14}\,Hz)}$

$\lambda = 1.282051 \times 10^{-6}\,m$ A/ correct λ

$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$, $S = 3$

$\frac{1}{(1.282051 \times 10^{-6}\,m)} = (1.097 \times 10^{7})\left[\frac{1}{3^2} - \frac{1}{L^2}\right]$

$\Rightarrow L = 4.9995$

$\therefore L = 5$

M/ valid method or L not rounded

E/ correct value as a whole number

AME 2

(d) Calculate the longest wavelength of light that is absorbed by a hydrogen atom in the n = 3 state.

The longest wavelength (shortest frequency) results in the electron's smallest jump ie. it moves from n=3 to n=4

A/ correct transistion recognised

$\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right) = (1.097 \times 10^{7})\left(\frac{1}{3^2} - \frac{1}{4^2}\right)$

$\frac{1}{\lambda} = 5.3326 \times 10^{5}$

$\therefore \lambda = 1.875 \times 10^{-6}\,m$

M/ correct value

AM 2

NZIP 2008

QUESTION TWO: ATOMIC SPECTRA

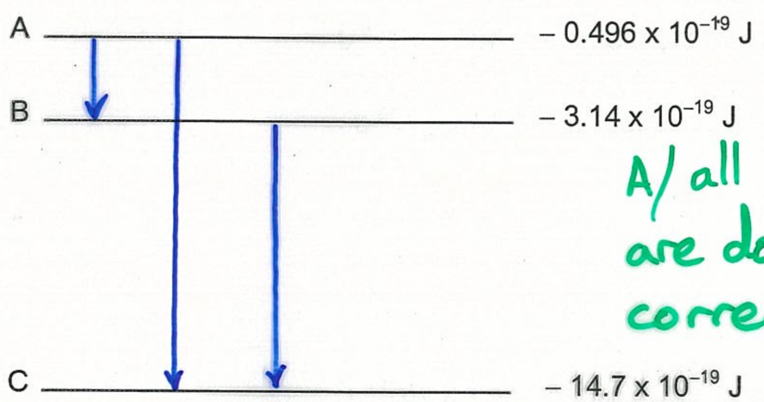
Assessor's use only

(a) Explain what is meant by the term "excitation energy".

A/ Excitation energy is the energy required to excite an atom from ground state, to a higher state (or lower state)

A₁

The diagram below shows three energy levels A, B and C within an atom.



A/ all three transitions are downward and correct.

A₁

(b) On the above diagram draw all possible transitions between these three energy levels that would result in photon emission.

(c) Between which two levels would the transition result in a photon with the **smallest** wavelength? Explain your answer.

A/ Transition: Transition A to C

$c=f\lambda$

Explanation: Because the smallest wavelength is associated with the largest frequency,

M/ which is related to the greatest energy change.

$E_\gamma = hf$

AM₁

A/ a series of dark lines in the full spectrum of colours

(d) What is an absorption spectrum? Explain how it is produced.

An atom can absorb the energy of a photon of light. If photons with a broad range of frequencies (energies) are incident on atoms, those photons that have the exact amount of energy to excite the atom from one of its energy levels to another will be absorbed and therefore photons of that frequency will be removed. A dark line will be observed at each of the wavelengths that correspond to the absorbed photons. This series of dark lines is known as the absorption spectrum. M/ Explanation incomplete.

E/ Correct, detailed.

AME₁

(e) Use the information given in the above diagram to calculate the wavelength of the light emitted when an electron falls from level A to C.

Speed of light, c = 3.00×10^8 m s^{-1}

Planck's constant, $h = 6.626 \times 10^{-34}$ J s

$\Delta E_{AC} = E_A - E_C$

$= (-0.496 \times 10^{-19} J) - (-14.7 \times 10^{-19} J)$

A/ $= 14.204 \times 10^{-19} J$ working & value for E

$f = \Delta E / h$

$= (14.204 \times 10^{-19} J) / (6.626 \times 10^{-34} Js)$

M/ $= 2.144 \times 10^{-15} Hz$ working & value for f OR λ incorrect using valid working with wrong E.

$\lambda = c/f$

$= (3.00 \times 10^{8} ms^{-1}) / (2.144 \times 10^{-15} Hz)$

wavelength = 1.40×10^{-7} m (3s.f.)

E/ valid working & correct value

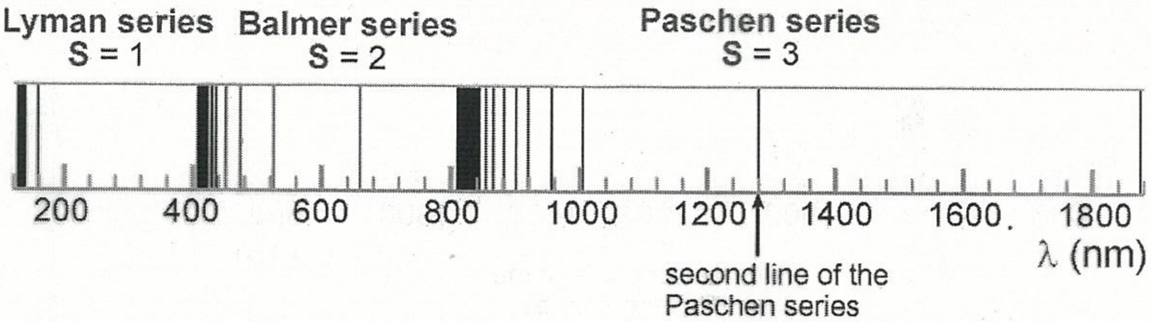
AME₂

NZIP 2005

QUESTION ONE:

Assessor's use only

Atomic Hydrogen Discrete Spectra



The above diagram represents a photograph of three series of discrete line spectra emitted by atomic hydrogen.

(a) Describe a line spectrum

A/ A line spectrum shows the individual wavelengths of light being observed.

A_1

(b) Explain what is meant by a discrete spectrum by comparing it to a white light spectrum.

M/ White light is a continuous spectrum showing all the wavelengths of visible light. Whereas a discrete line spectrum shows only certain wavelengths

M_1

(c) The arrow in the above diagram indicates the second line of the Paschen series. Using the calibrated scale, write down the value of the wavelength of this line in *SI units* (1 nm = 10^{-9}m).

A/ 1280×10^{-9} m

A_2

(d) By selecting a suitable formula, calculate the wavelength of the second line of the Paschen series (Rydberg's constant = $1.097 \times 10^7 \text{ m}^{-1}$).

use $\frac{1}{\lambda} = R\left(\frac{1}{S^2} - \frac{1}{L^2}\right)$ A/ correct formula and substitution

$\frac{1}{\lambda} = (1.097 \times 10^7 \text{m}^{-1})\left(\frac{1}{3^2} - \frac{1}{5^2}\right)$

$\frac{1}{\lambda} = 7.8008 \times 10^5 \text{m}^{-1}$ $\therefore \lambda = 1282 \times 10^{-9} \text{ m}$ (4 s.f.)

M/ correct value

AM$_2$

(e) Give a precise description of the nature of the energy emitted by the second line of the Paschen series.

A/ The second line of the Paschen series is INFRA-RED.

A$_1$

NZIP 2005

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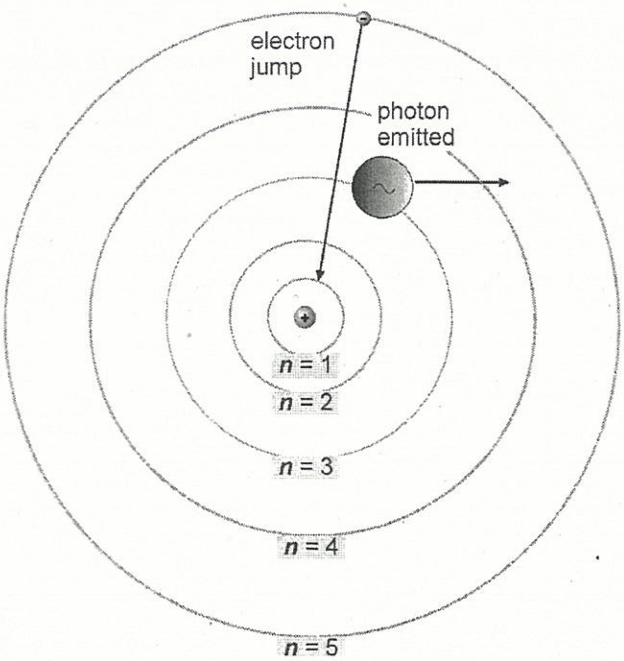
QUESTION THREE:



The diagram shows the Rutherford-Bohr model of the hydrogen atom.

(a) Describe what is happening in the diagram

A/ The electron in the hydrogen atom is jumping from a higher state (allowed orbit n=5) to a lower state (ground, n=1). The energy the electron loses in making the jump is emitted as a photon.

A.

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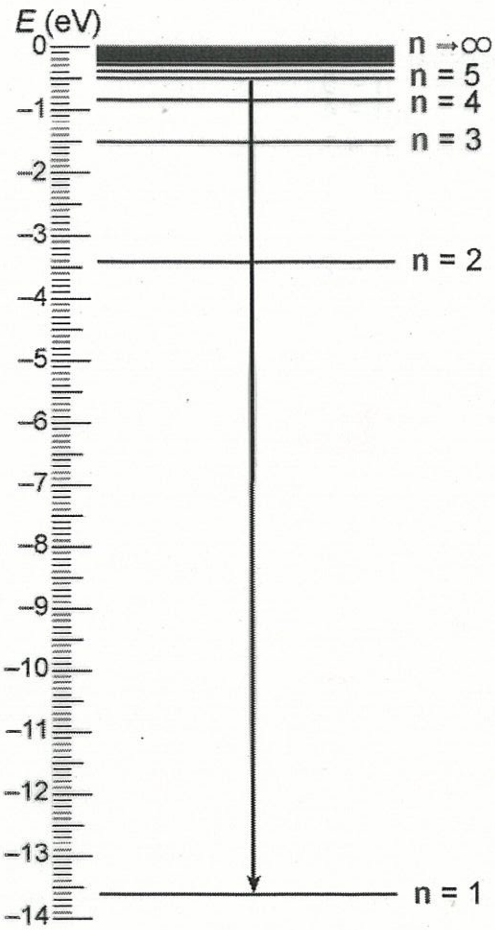
(b) This diagram shows an energy level diagram fro the allowed states of the electron in the hydrogen atom. The energy E is given in the units of electron-volts (eV). Calculate the energy in SI units of the photon emitted for the electron jump shown in the diagram of 3 (a) above.
(Charge on the electron e = 1.602 x 19^{-19} C).

Energy Level Diagram



$\Delta E = E_5 - E_1$

$= (-0.5\,\text{eV}) - (-13.6\,\text{eV})$

$= +13.1\,\text{eV}$

A/ correct ΔE in eV

$\Delta E = (13.1\,\text{eV}) \times (1.602 \times 10^{-19}\,\text{J/eV})$

$= 2.0986 \times 10^{-18}\,\text{J}$

$= 2.10 \times 10^{-18}\,\text{J}$ (3 s.f.)

M/ correct ΔE in J

AM_2