A2 Level Physics

Chapter 16 – Astrophysics and Cosmology

16.2.2 Electromagnetic Radiation from Stars

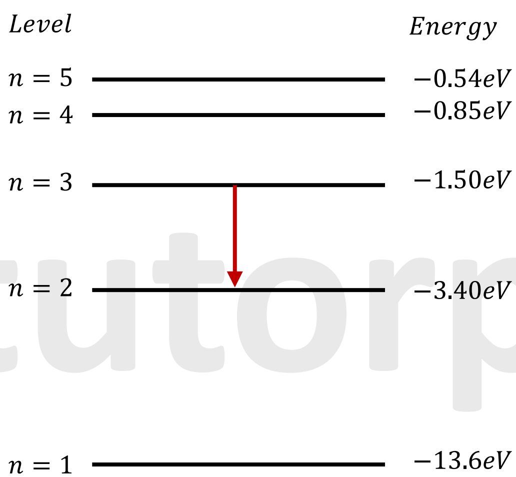
Worked Examples

Energy Levels of Electrons

Exam Style Question 1

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

Calculate the wavelength of the photon produced by an electron transition from $n = 3$ to $n = 2$.



Energy Levels of Electrons

Exam Style Question 1

1) Find the difference in energy between the two energy levels. This will be the photon energy.

$$\Delta E = E_1 - E_2 = 3.40 - 1.50 = 1.90\ eV$$

Because all of the energies are negative, you can just subtract their magnitudes and ignore the minuses.

2) Convert the energy from eV to joules. This will help you find the wavelength later.

$$1\ eV = 1.60 \times 10^{-19}\ J$$

$$\therefore 1.90\ eV \times 1.60 \times 10^{-19} = 3.04 \times 10^{-19}\ J$$

3) Substitute this energy, the speed of light and the Planck constant into the equation and find the wavelength:

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

$$3.04 \times 10^{-19} = \frac{(6.63 \times 10^{-34}) \times (3.00 \times 10^{8})}{\lambda}$$

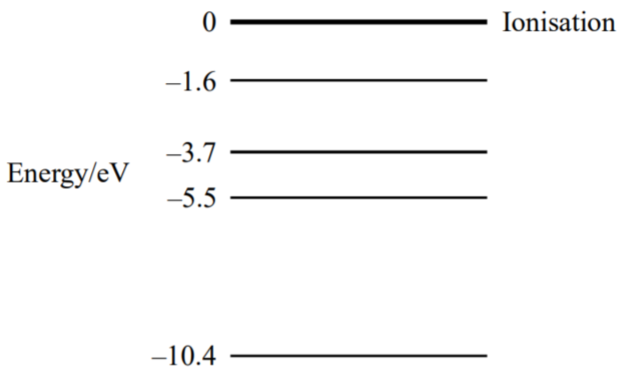
$$\therefore \lambda = \frac{(6.63 \times 10^{-34}) \times (3.00 \times 10^{8})}{3.04 \times 10^{-19}}$$

$$\lambda = 6.54 \times 10^{-7}\ m\ (3\ s.f.)$$

Energy Levels of Electrons

Exam Style Question 2

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



a) Calculate the ionisation energy in joules for an electron in the $-10.4\ eV$ level.

b) An electron has been excited to the $-1.6\ eV$ energy level. Show on the diagram all the possible ways it can return to the $-10.4\ eV$ level.

c) Which change in energy levels will give rise to a yellowish line ($\lambda = 600\ nm$) in the mercury spectrum?

Energy Levels of Electrons

Exam Style Question 2

a) Calculate the ionisation energy in joules for an electron in the $-\mathbf{10.4}\ \boldsymbol{eV}$ level.

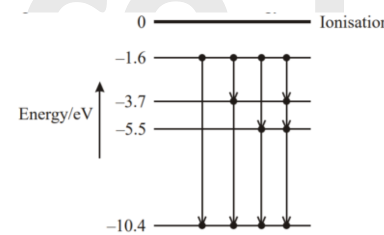
To go from eV to Joules you just need to times by $1.6 \times 10^{-19}\ J$

$$10.4\ eV \times 1.6 \times 10^{-19}\ J = 1.66 \times 10^{-18}\ J$$

b) An electron has been excited to the $-\mathbf{1.6}\ \boldsymbol{eV}$ energy level. Show on the diagram all the possible ways it can return to the $-\mathbf{10.4}\ \boldsymbol{eV}$ level.

There are 4 routes the electron can take to go from $-1.6\ eV$ to $-10.4\ eV$ e.g.:

1) $-1.6\ eV \rightarrow -10.4\ eV$
2) $-1.6\ eV \rightarrow -3.7\ eV \rightarrow -10.4\ eV$
3) $-1.6\ eV \rightarrow -5.5\ eV \rightarrow -10.4\ eV$
4) $-1.6\ eV \rightarrow -3.7\ eV \rightarrow -5.5\ eV \rightarrow -10.4\ eV$



c) Which change in energy levels will give rise to a yellowish line ($\boldsymbol{\lambda} = \mathbf{600}\ \boldsymbol{nm}$) in the mercury spectrum?

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

$$E = \frac{(6.63 \times 10^{-34}\ J\ s)(3 \times 10^{8}\ m\ s^{-1})}{(600 \times 10^{-9}\ m)}$$

$$E = \frac{(3.315 \times 10^{-19} J)}{1.6 \times 10^{-19}} = 2.07\ eV \approx 2.1\ eV$$

Therefore the change in energy levels is from -1.6 to -3.7 (as $3.7 - 1.6 = 2.1$).

Energy Levels of Electrons

Exam Style Question 3

(a) What is a line spectrum?

(b) Describe an absorption spectrum.

(c) Calcium has a line spectrum, which includes the spectral line at a wavelength of $393\ nm$. Calculate the frequency of this line.

(d) What information about a star can be deduced from its spectrum?

Energy Levels of Electrons

Exam Style Question 3

(a) What is a line spectrum?

A series of lines on a dark/white background.

(b) Describe an absorption spectrum.

Dark lines against a background of continuous spectrum.

(c) Calcium has a line spectrum, which includes the spectral line at a wavelength of $393\ nm$. Calculate the frequency of this line.

Use $v = f\lambda$ and rearrange for f:

$$f = \frac{v}{\lambda} = \frac{3 \times 10^{8}\ m\ s^{-1}}{393 \times 10^{-9}\ m}$$

$$f = 7.63 \times 10^{14}\ Hz$$

(d) What information about a star can be deduced from its spectrum?

Its chemical composition and surface temperature.

Energy Levels of Electrons

Exam Style Question 4

The Sun behaves as an approximate black-body radiator with peak energy radiation occurring at a wavelength of $5.2 \times 10^{-7}\ m$.

Show that the Sun has a surface temperature of about $6000\ K$.

Energy Levels of Electrons

Exam Style Question 4

Show that the Sun has a surface temperature of about $6000\ K$.

Use $\lambda_{max}\, T = 2.9 \times 10^{-3}\ m\ K$ rearrange for T

$$T = \frac{2.9 \times 10^{-3}\ m\ K}{\lambda_{max}} = \frac{2.9 \times 10^{-3}\ m\ K}{5.2 \times 10^{-7}\ m}$$

$$T = 5577\ K \approx 6000\ K$$

Energy Levels of Electrons

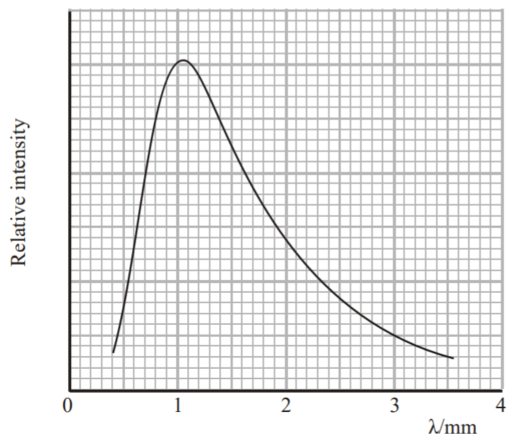
Exam Style Question 5

Wien's law can be written as

$$\lambda_{max}\,T = 2.9 \times 10^{-3}\ m\ K$$

(a) Explain clearly what is meant by each symbol in Wien's law.

The graph shows the wavelength distribution for radiation detected by the COBE satellite.



(b) Use the graph to determine the temperature of the source of these emissions.

Energy Levels of Electrons

Exam Style Question 5

(a) Explain clearly what is meant by each symbol in Wien's law.

λ_{max} = peak wavelength associated with max. intensity in m
T = absolute surface temperature in K
$Wien\ constant$ = $2.9 \times 10^{-3}\ m\ K$

(b) Use the graph to determine the temperature of the source of these emissions.

Use $\lambda_{max}\,T = 2.9 \times 10^{-3}\ m\ K$ rearrange for T

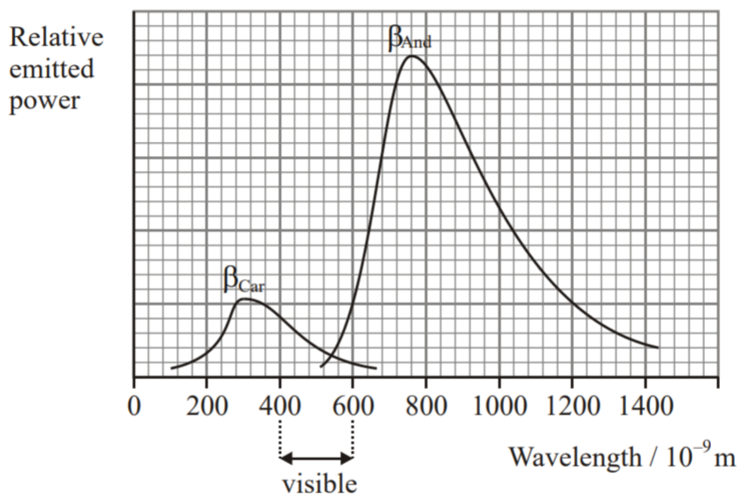
$$T = \frac{2.9 \times 10^{-3}\ m\ K}{\lambda_{max}} = \frac{2.9 \times 10^{-3}\ m\ K}{1.05 \times 10^{-3}\ m}$$

$$T = 2.76\ K$$

Energy Levels of Electrons

Exam Style Question 6

The graph shows the energy distribution in the spectra of two stars β_{Car} and β_{And}.



(a) What can be deduced about the colours of the two stars from the graph?

(b) Estimate the surface temperature of β_{And}.

(c) The luminosity of β_{Car} is $2.0 \times 10^{28}\ W$ and it has a surface temperature of $9300\ K$. Calculate the surface area of β_{Car}.

Energy Levels of Electrons

Exam Style Question 6

(a)What can be deduced about the colours of the two stars from the graph?

β_{Car} is bluish because it is in the blue part of the visible spectrum and β_{And} is reddish is in the red end of the visible spectrum.

(b) Estimate the surface temperature of β_{And}.

Use $\lambda_{max}\ T = 2.9 \times 10^{-3}\ m\ K$ rearrang for T

$$T = \frac{2.9 \times 10^{-3}\ m\ K}{\lambda_{max}} = \frac{2.9 \times 10^{-3}\ m\ K}{760 \times 10^{-9}\ m}$$

$$T = 3816\ K$$

(c) The luminosity of β_{Car} is $2.0 \times 10^{28}\ W$ and it has a surface temperature of $9300\ K$. Calculate the surface area of β_{Car}.

Use$L = 4\pi r^2 T^4 \sigma$ where $surface\ area = 4\pi r^2 = A$

$$\therefore L = AT^4\sigma$$

So rearrange for A:

$$A = \frac{L}{T^4\sigma} = \frac{2.0 \times 10^{28}\ W}{(9300\ K)^4(5.67 \times 10^{-8}\ Wm^{-2}k^{-4})}$$

$$A = 4.7 \times 10^{19}\ m^2$$

Please see **'16.2.1 Electromagnetic Radiation from Stars notes'** pack for exam style questions.

For more revision notes, tutorials and worked examples please visit **www.tutorpacks.co.uk.**