Announcements

<u>This week:</u>

Content: Concept videos 1, 2, and 3 and the associated in-class practice problems

NEXT WEEK's CONTENT IS POSTED ON MYCOURSES

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<u>All lecture slides (annotated with answers) will be posted at the end of the week</u>

SciLearn
Peer Collaboration

Weekdays, 3-5 pm
2001 McGill College
Sept. 9 - Nov. 29

A collaborative learning environment for students in U0 & U1 Science courses!

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- Complete assignments together
- Receive guidance from TAs & professors
- Make friends in your classes
- Enjoy study snacks

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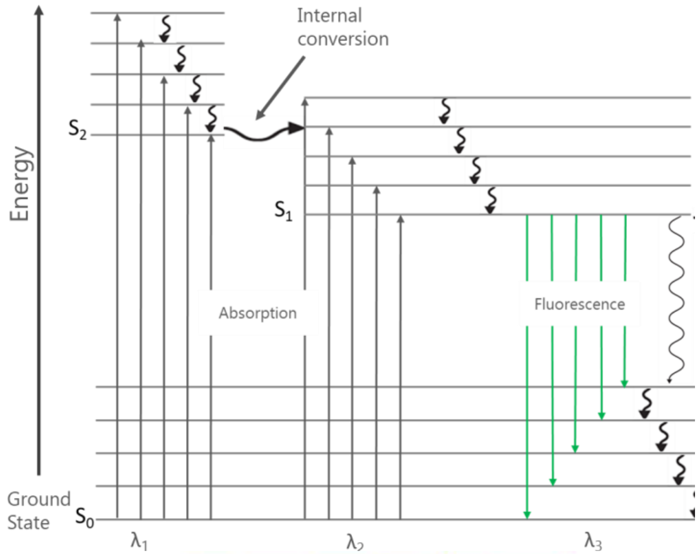
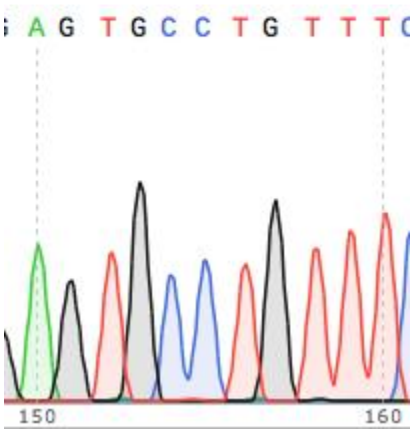
Light is made up of particles – so what? Why you *should* care!



Certain chemical molecules fluoresce! This behaviour is because *photons of specific energy* are absorbed by these molecules and, after a few processes, *photons* of lower energy are emitted, as the excited electron return to ground state!



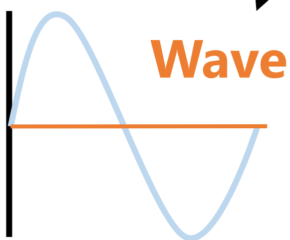
Fluorescence is very sensitive (the signal changes even at very very small concentrations), and hence was used (among many other things) as the readout for qPCR in DNA/RNA sequencing!

qPCR/PCR – which we are now so familiar with (PCR-testing of COVID-19) - is a technology that has enabled rapid and accurate detection of multiple analytes (including viruses)!

There is (a lot of) other chemistry/science involved in development of these advance technologies, but understanding the fundamental processes that enable the advancement of these technologies is very important!

Review Notes: Wave nature of light

Speed: The **distance** the wave moves **per unit time**



Wavelength (λ)

Frequency (ν)

Speed of light in vacuum (all different forms of electromagnetic radiation)

$\boxed{c = 2.998 \times 10^{8}\ \mathrm{ms}^{-1}}$ This is a constant

$$c = \lambda \nu$$

What does this equation tell you about the relationship between speed of light, wavelength, and frequency?

*For all calculations/questions consider the speed of light in vacuum, unless specified otherwise

Practice Problem 1 (Electromagnetic Radiation)

What is the wavelength (in nm) of an electromagnetic wave whose frequency is 4.07×10^{15} Hz? **(3 sig figs)**

Given:

Frequency (ν) = 4.07×10^{15} Hz = $4.07 \times 10^{15}\ s^{-1}$

Known:

c (speed of light) = $2.998 \times 10^{8}\ ms^{-1}$ (Constant)

$c = \lambda \times \nu$

$2.998 \times 10^{8}\ ms^{-1} = \lambda \times 4.07 \times 10^{15}\ s^{-1}$

$\frac{2.998 \times 10^{8}}{4.07 \times 10^{15}}\ m = \lambda$

$1m = 10^{9}$ nm

$\lambda = 7.37 \times 10^{-8}\ m = 73.7$ nm slido

Identify the correct statement from the choices:

ⓘ Start presenting to display the poll results on this slide.

Practice Problem 2 (Electromagnetic Radiation)

Identify the correct statement from the choices:

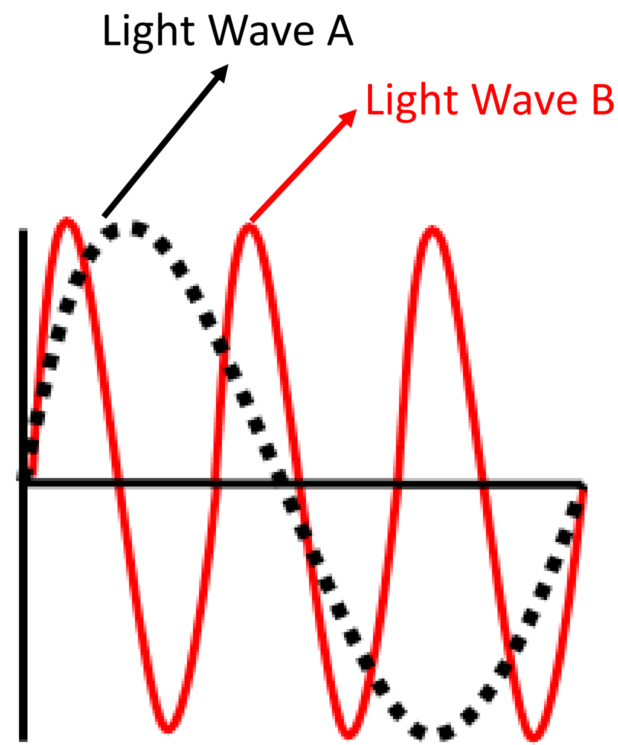
A. Light wave A has a lower frequency than B

B. The frequency of light wave A is $1 s^{-1}$ and that of B is $3 s^{-1}$

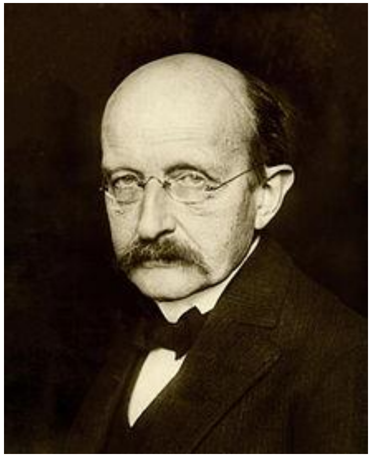
C. Light wave A has a higher frequency than B

D. Both A and B are correct

E. Both B and C are correct



Review Notes: Blackbody Radiation



Max Planck

Planck: Derived a mathematical expression to describe the phenomenon of blackbody radiation by theorizing that **energy only assumed certain values (quantized).**

Related energy to frequency.

$E = nh\nu$; Energy is quantized

Energy of the radiation

Quantization Factor

n = 1, 2……

$E = nh\nu$

Frequency

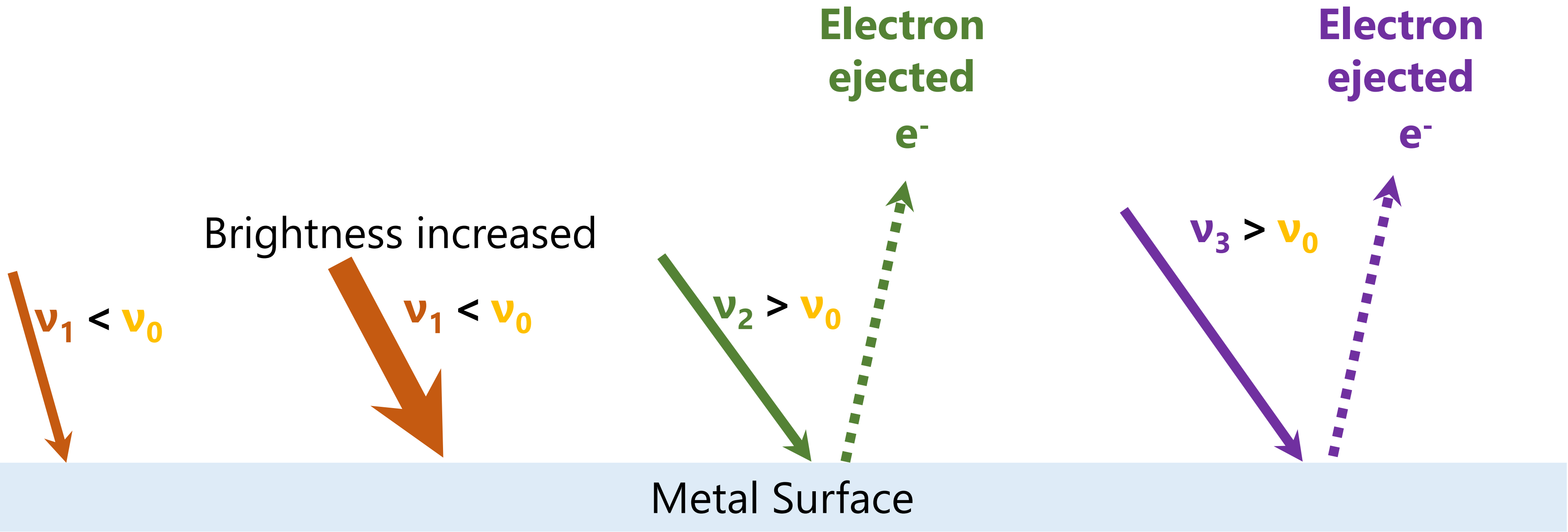
$E = h\nu$

For n= 1

Planck's Constant: $h = 6.62606876 \times 10^{-34}$ J•s

Review Notes: Photoelectric Effect

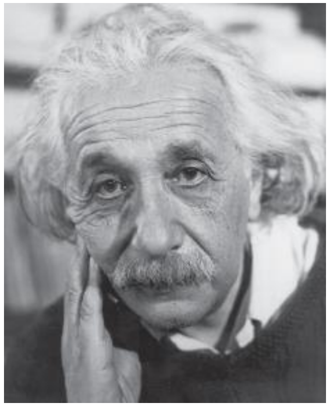
Photoelectric effect



Light with $\nu \geq \nu_0$ could eject electrons from the metal surface

ν_0 – Threshold Frequency

Review Notes: Photoelectric Effect



Work function depends on the threshold frequency

$\Phi = h\nu_0$

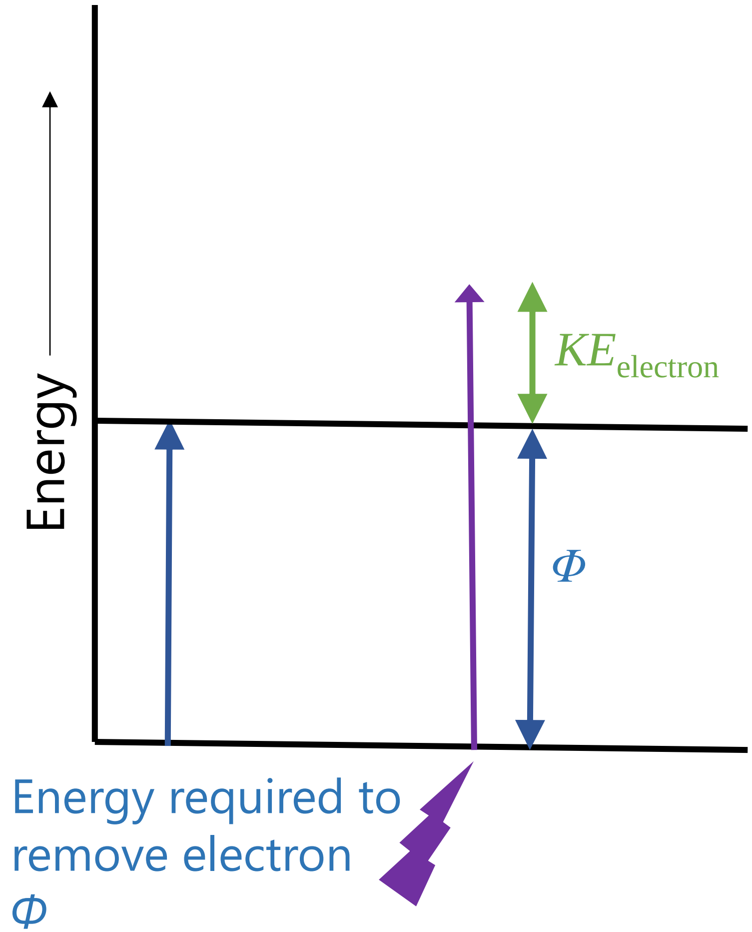
Light comes in packets - photons

$$E_{photon} = KE_{electron} + \text{Work Function}_{metal}$$

$$h\nu = \tfrac{1}{2}m_e u^2 + \Phi$$

$$h\nu = \tfrac{1}{2}m_e u^2 + h\nu_0$$

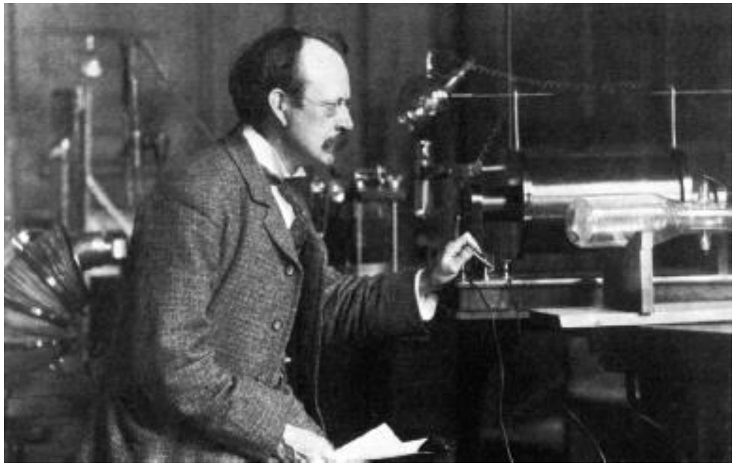
frequency velocity

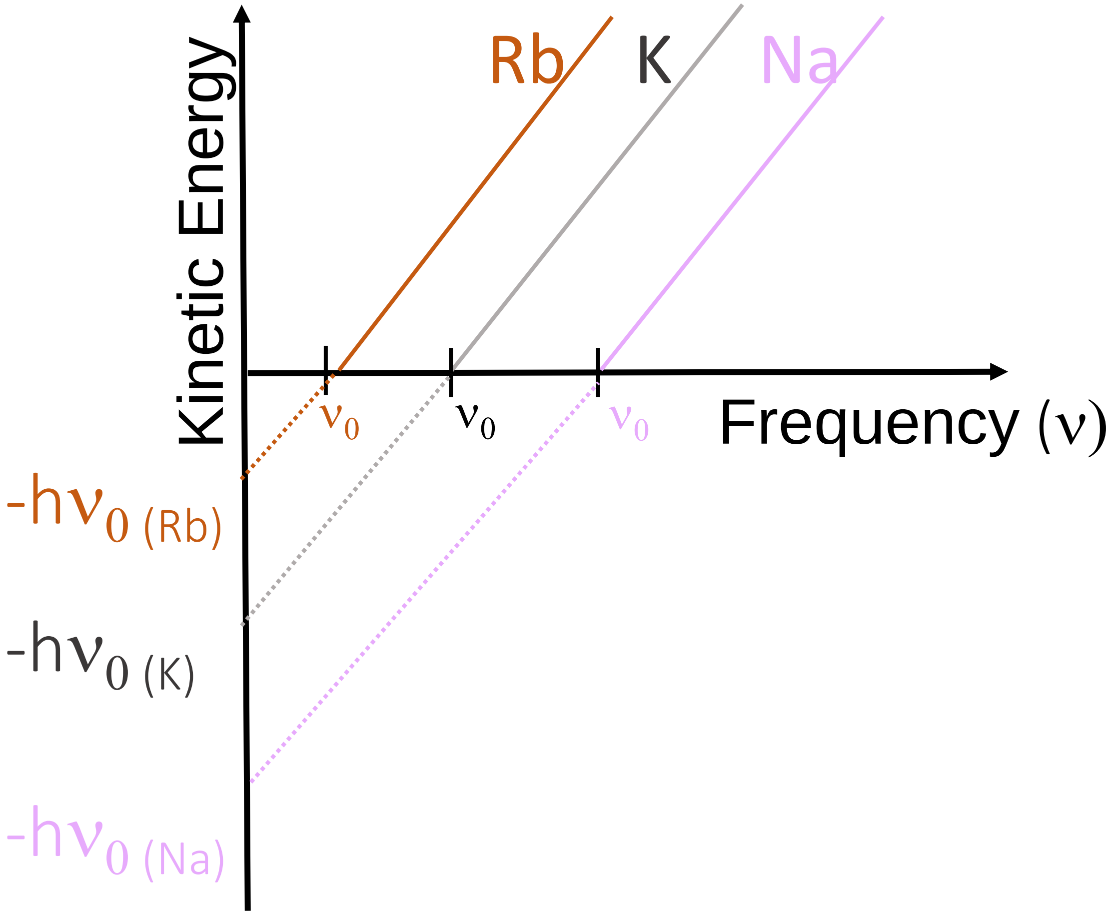


$h\nu > \Phi$

Photoelectric Effect

Experiments by JJ Thomson confirmed Einstein explanations!





$h\nu = \frac{1}{2}m_e v^2 + \Phi$

$h\nu = \frac{1}{2}m_e v^2 + h\nu_0$

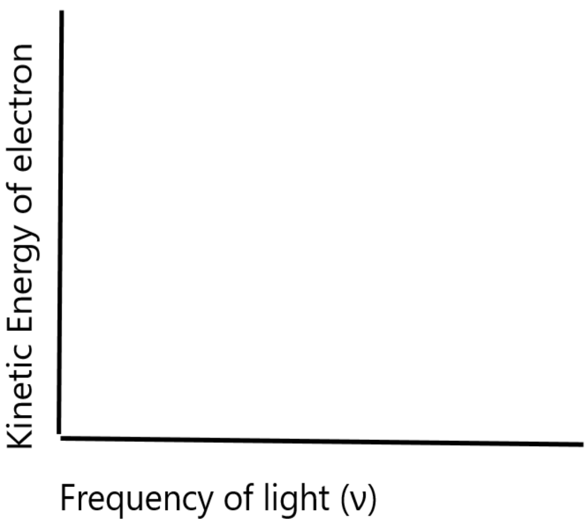
$\frac{1}{2}m_e v^2 = h\nu - h\nu_0$

$y = mx + c$

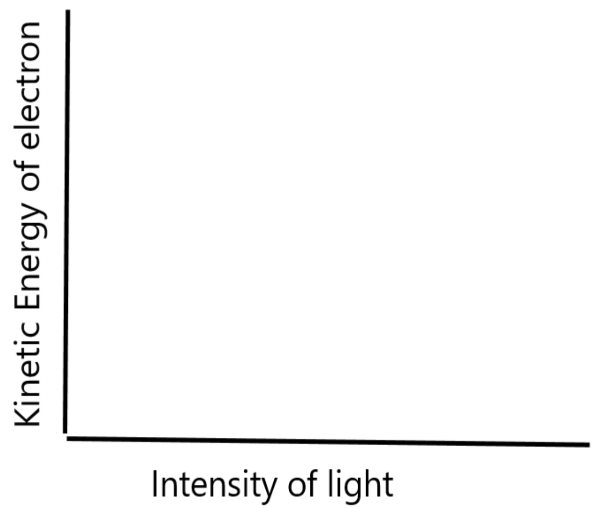
Practice Problem 3 (Photoelectric Effect)

Based on photoelectric effect, draw the plots for the following and explain

A. Kinetic energy of electron versus frequency of light



B. KE of electron versus intensity (or brightness) of light. (At frequency above threshold frequency)



Practice Problem 3 (Photoelectric Effect)

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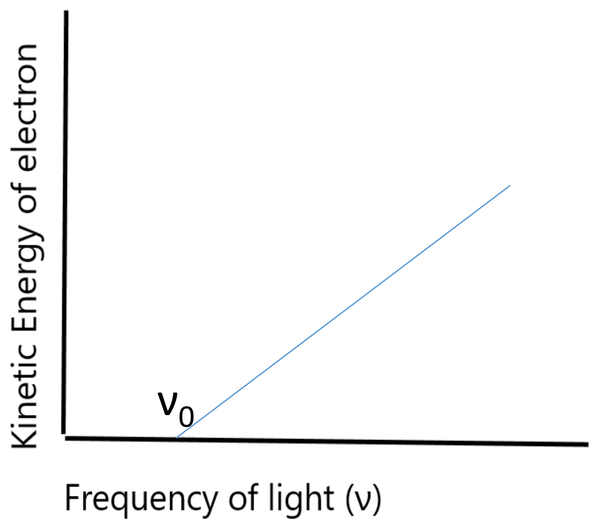
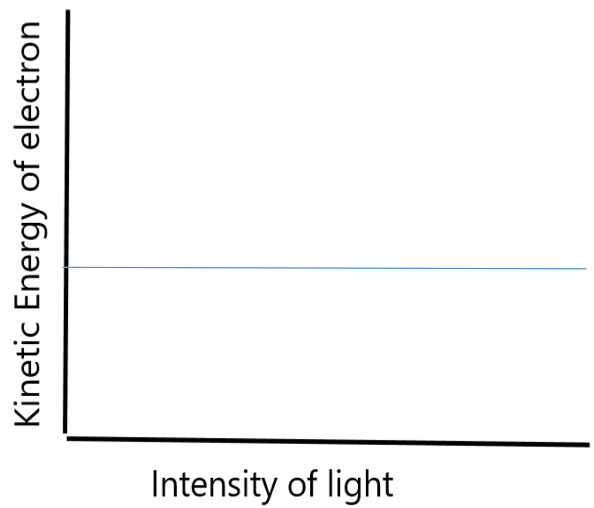


B. KE of electron versus intensity (or brightness) of light. (At frequency above threshold frequency)



Practice Problem 4 (Photoelectric Effect)

A particular metal has a work function of 1.907 eV. What will the velocity of the removed electron be if light of wavelength 550 nm is applied to the metal surface?

I have solved the problem step by step (outlining each steps) – you can also do this without the step by step breakdown.

You can also get to the answer through different steps – all of that is okay but you must always show your work in exams!

For questions like these, I will tell you in questions how many sig figs I am looking for in the final answer.

We do want you to know and understand significant figures and their relevance but it will be applied in the labs and not assessed in lectures.

Practice Problem 4 (Photoelectric Effect)

A particular metal has a work function of 1.907 eV. What will the velocity of the removed electron be if light of wavelength 550 nm is applied to the metal surface? **(1 eV = 1.6022 x 10^{-19} J)**

$$E_{\text{photon}} = KE_{\text{electron}} + \text{Work Function}_{\text{metal}} \qquad c = \lambda \upsilon$$

$$h\upsilon = \tfrac{1}{2} m_e u^2 + \Phi$$

Given

Work function
Wavelength of light

To calculate

Velocity of electron

Constants

$c = 2.998 \times 10^{8}\ \text{ms}^{-1}$

$h = 6.626 \times 10^{-34}\ \text{Js}$

$\text{m}_{\text{electron}} = 9.109 \times 10^{-31}\ \text{kg}$

$N_A = 6.022 \times 10^{23}\ \text{mol}^{-1}$

$1\ \text{J} = 1\ \text{kg m}^2\ \text{s}^{-2}$

Practice Problem 4

A particular metal has a work function of 1.907 eV. What will the velocity of the removed electron be if light of wavelength 550 nm is applied to the metal surface? (1 eV = 1.6022 x 10^{-19} J)

Step 1: Calculate energy of the photon from the given wavelength

$$E_{\text{photon}} = h\upsilon = hc/\lambda = \frac{\overset{h}{(6.626\times10^{-34}\ \text{J}\bullet\text{s})} \times \overset{c}{(2.998 \times 10^{8}\ \text{ms}^{-1})}}{\underset{\lambda}{(550\ \text{nm})}}$$

$$\frac{(6.626\times10^{-34}\ \text{J}\bullet\text{s}) \times (2.998 \times 10^{8}\ \text{ms}^{-1})}{(550\times10^{-9}\ \text{m})}$$

$$\boxed{= \ 3.6118\ldots \times10^{-19}\ \text{J}}$$

Practice Problem 4

A particular metal has a work function of 1.907 eV. What will the velocity of the removed electron be if light of wavelength 550 nm is applied to the metal surface? (1 eV = 1.6022 x 10^{-19} J)

$$E_{photon} = KE_{electron} + \text{Work Function}_{metal}$$

$$h\upsilon = \tfrac{1}{2}m_e u^2 + \Phi$$

Step 2: Convert the work function to Joules

$$\Phi = 1.907 \text{ eV} \quad = 1.907 \text{ eV} \times 1.6022 \times 10^{-19} \text{ J/eV}$$

$$\boxed{= 3.0554.. \times 10^{-19} \text{ J}}$$

Practice Problem 4

A particular metal has a work function of 1.907 eV. What will the velocity of the removed electron be if light of wavelength 550 nm is applied to the metal surface?

$$h\upsilon = \frac{1}{2}m_e u^2 + \Phi$$

$m_e = 9.109 \times 10^{-31}$ kg

$J = kg\ m^2 s^{-2}$

$$\frac{1}{2}m_e u^2 = h\upsilon - \Phi$$

Step 3: Calculate the velocity of the electron

$$\frac{1}{2}m_e u^2 = 3.6118 \times 10^{-19}\ J - 3.0554 \times 10^{-19}\ J$$

$$\frac{1}{2}m_e u^2 = 0.5564.. \times 10^{-19}\ kg\ m^2 s^{-2}$$

$$u^2 = \frac{2 \times 0.5564 \times 10^{-19}}{9.109 \times 10^{-31}}\ m^2 s^{-2} \qquad u = \sqrt{\frac{2 \times 0.5564 \times 10^{-19}}{9.109 \times 10^{-31}}}$$

$$= \boxed{3.50 \times 10^{5}\ ms^{-1}}$$

Practice Problem 5 (Photoelectric Effect)

The longest wavelength of light that causes electrons to be ejected from the surface of a metal plate is 300 nm. What is the wavelength (in nm) of the light applied to this metal surface if the ejected electron has a velocity of 1.21×10^6 ms^{-1}? Give your answer to 3 significant figures

Practice Problem 5

The longest wavelength of light that causes electrons to be ejected from the surface of a metal plate is 300 nm. What is the wavelength (in nm) of the light applied to this metal surface if the ejected electron has a velocity of 1.21 x 10^6 ms^{-1}? Give your answer to 3 significant figures

Step 1: Longest wavelength given – convert to frequency – this is threshold frequency

$$c = \lambda \upsilon$$

$$\upsilon_0 = (2.998 \times 10^8)\ ms^{-1} / (300 \times 10^{-9})\ m$$

$$\upsilon_0 = 10^{15}\ s^{-1}$$

Step 2: This is the threshold frequency – So we can now calculate work potential

$$\Phi = h\upsilon_0$$

$$\Phi = (6.626 \times 10^{-34}\ J \cdot s) \times (10^{15}\ s^{-1}) = \mathbf{6.626 \times 10^{-19}\ J}$$

Practice Problem 5

The longest wavelength of light that causes electrons to be ejected from the surface of a metal plate is 300 nm. What is the wavelength (in nm) of the light applied to this metal surface if the ejected electron has a velocity of 1.21×10^{6} ms^{-1}? Give your answer to 3 significant figures

Step 3: Calculate Kinetic Energy of electron

$KE = \frac{1}{2} m_e v^2$

$KE = \frac{1}{2} (9.109 \times 10^{-31}) (1.21 \times 10^{6})^2 \ kg\ m^2 s^{-2}$

$KE = 6.668 \times 10^{-19}$ J

CONSTANT

$m_e = 9.109 \times 10^{-31}$ kg

$J = kg\ m^2 s^{-2}$

Practice Problem 5

The longest wavelength of light that causes electrons to be ejected from the surface of a metal plate is 300 nm. What is the wavelength (in nm) of the light applied to this metal surface if the ejected electron has a velocity of 1.21 x 10^6 ms^{-1}? Give your answer to 3 significant figures

Step 4: Calculate wavelength of photon

$h\upsilon = \frac{1}{2}m_e v^2 + \Phi$

$hc/\lambda = \frac{1}{2}m_e v^2 + \Phi$

$hc/\lambda = 6.668 \times 10^{-19} + 6.626 \times 10^{-19}$ J

Relating frequency and wavelength

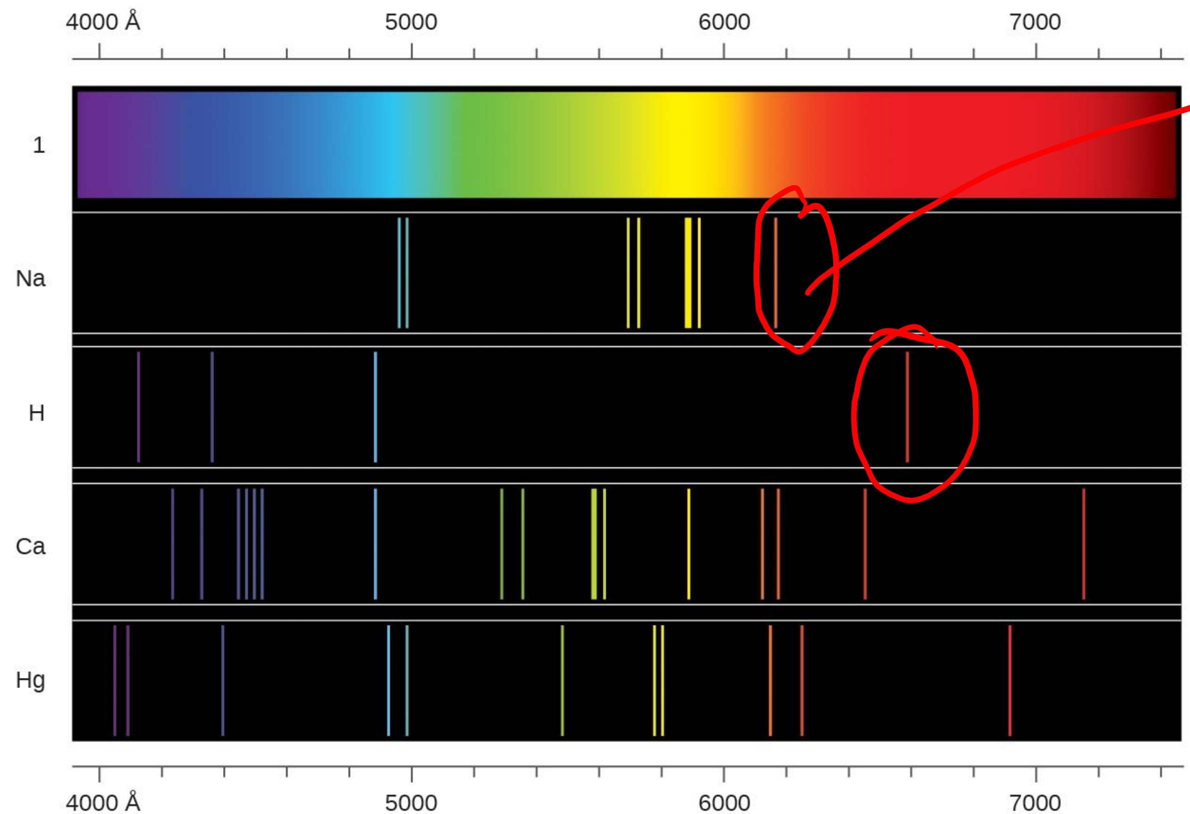
$c = \lambda\upsilon$

CONSTANTS

$c = 2.998 \times 10^8$ ms^{-1}

$h = 6.626 \times 10^{-34}$ Js

Atomic Spectra



$\frac{1}{\lambda} = R\left(\frac{Z^2}{n_1^2} - \frac{Z^2}{n_2^2}\right)$

Exciting a gas at low partial pressure using an electrical current, or heating it, - then measuring the emission.
The emission is a line spectra i.e. there is not a continuous spectrum (see 1 above) but discrete lines (see Na/H/Ca/Hg) characteristic for each element.
These lines are emissions at specific wavelength/frequency/energy. So what is happening here

Practice Problem 6 (Atomic Spectra)

Calculate the wavelength (nm) corresponding to the emission line resulting from a transition of n=3 to n=2 in hydrogen atom?

$$\frac{1}{\lambda} = R\left(\frac{Z^2}{n_1^2} - \frac{Z^2}{n_2^2}\right)$$

Z is the atomic number;
For: Hydrogen it is 1, Helium it is 2, Lithium it is 3 etc.

n_1 and n_2 are positive integers with $n_2 > n_1$
So, n_2 = 3; and n_1 = 2 in this question

R is the Rydberg constant (1.096776 x 10^7 m^{-1})

$$\frac{1}{\lambda} = (1.096776\ x\ 10^7)\left(\frac{1^2}{2^2} - \frac{1^2}{3^2}\right)$$

$\frac{1}{\lambda} = 1.524 \times 10^6\ m^{-1}$

$\lambda = \frac{1}{1.524 \times 10^6}\ m$

$$\frac{1}{\lambda} = (1.096776\ x\ 10^7)\ (0.1388888) = (1.524\ x\ 10^6)\ m^{-1}$$

λ = $(6.5617\ x\ 10^{-7})$ m = 656.17 nm (or 656 nm also okay or 6.56 x 10^2 nm)