

Photoelectric Effect

Calculations

$$E=hf$$

ENERGY PER PHOTON

$$E = hf$$

- E = Energy per photon
- f = frequency of light
- h = Planck's constant = $6,63 \times 10^{-34} \text{ J}\cdot\text{s}$

Question 1

How much energy does each photon of UV light of wavelength 288 nm have?

Solution: Given and required

Required: E

Given: $\lambda = 288 \text{ nm}$

Known: $h = 6,63 \times 10^{-34} \text{ J}\cdot\text{s}$

Equation: $E = hf$

Solution: how to find f

$$\textit{frequency of light} = \frac{\textit{speed of light}}{\textit{wavelength of light}}$$

$$f = \frac{c}{\lambda}$$

$$f = \frac{3 \times 10^8 \text{ m} \cdot \text{s}^{-1}}{\lambda}$$

Solution: finding f

$$E = hf$$

$$f = \frac{3 \times 10^8 \text{ m} \cdot \text{s}^{-1}}{\lambda}$$

Given: $\lambda = 288 \text{ nm}$

Known: $\text{nm} = 10^{-9} \text{ m}$

Therefore $288 \text{ nm} = 288 \times 10^{-9} \text{ m}$

Solution: finding f

$$E = hf$$

$$f = \frac{3 \times 10^8 \text{ m} \cdot \text{s}^{-1}}{\lambda}$$

$$f = \frac{3 \times 10^8 \cancel{\text{m}} \cdot \text{s}^{-1}}{288 \times 10^{-9} \cancel{\text{m}}}$$

Given: $\lambda = 288 \text{ nm}$

Known: $\text{nm} = 10^{-9} \text{ m}$

Therefore $288 \text{ nm} = 288 \times 10^{-9} \text{ m}$

$$\text{s}^{-1} = \frac{1}{\text{s}} = \text{Hz}$$

Solution: finding f

$$E = hf$$

$$f = \frac{3 \times 10^8 \text{ m} \cdot \text{s}^{-1}}{\lambda}$$

$$f = \frac{3 \times 10^8 \cancel{\text{m}} \cdot \text{s}^{-1}}{288 \times 10^{-9} \cancel{\text{m}}}$$

$$f = 1,04 \times 10^{15} \text{ Hz}$$

Solution: finding E

$$E = hf$$

Required: E

Known: $h = 6,63 \times 10^{-34} \text{ J}\cdot\text{s}$

$f = 1,04 \times 10^{15} \text{ Hz}$

Solution: finding E

$$E = hf$$

$$= 6,63 \times 10^{-34} \text{ J}\cdot\text{s} \times 1,04 \times 10^{15} \text{ Hz}$$

$$= 6,63 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}} \times 1,04 \times 10^{15} \cancel{\text{s}}^{-1}$$

$$= 6,91 \times 10^{-19} \text{ J}$$



PHOTON



PHOTON

carries amount of

Energy = $h\nu$



PHOTON

carries amount of

Energy $\propto f$



PHOTON

carries amount of

$$\text{Energy} = hf$$



PHOTON

carries amount of

$$\text{Energy} = hf$$

gives ALL to ONE



ELECTRON

in

metal



PHOTON

carries amount of

$$\text{Energy} = hf$$

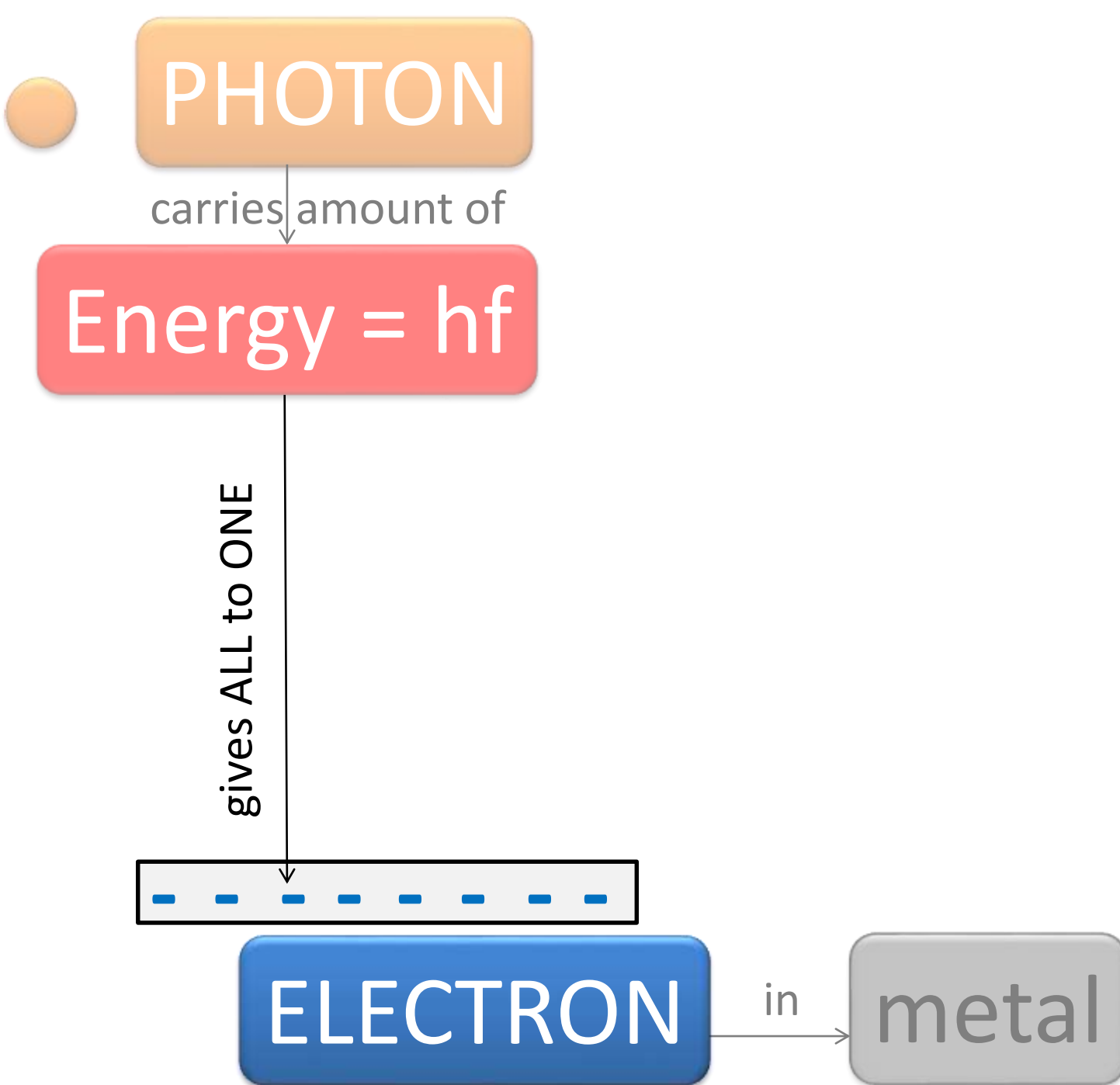
gives ALL to ONE



ELECTRON

in

metal





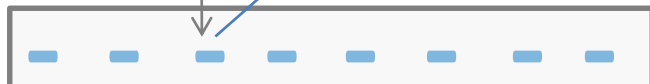
PHOTON

carries amount of

$$\text{Energy} = hf$$

gives ALL to ONE

photoelectric emission



ELECTRON

in

metal

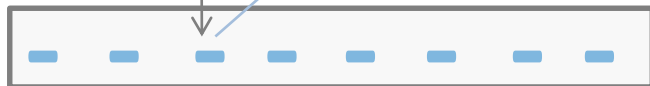


PHOTON

carries amount of

$$\text{Energy} = hf$$

gives ALL to ONE



photoelectric emission

for

$$W_0$$

needs $\geq$

type determines

ELECTRON

in

metal

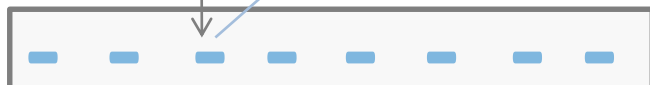


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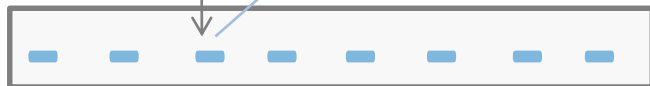


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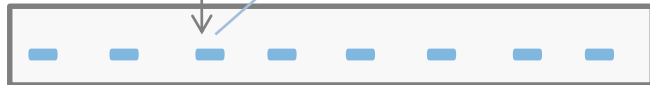
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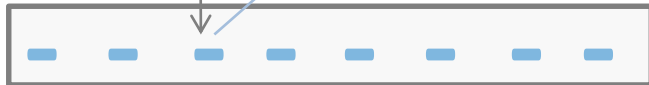


PHOTON

carries amount of

$$\text{Energy} = hf$$

gives ALL to ONE



ELECTRON

in

metal

$$KE_{\text{max}} = hf - hf_0$$

for surface electrons occurs with

photoelectric emission

for

$$W_0 = hf_0$$

needs $\geq$

type determines

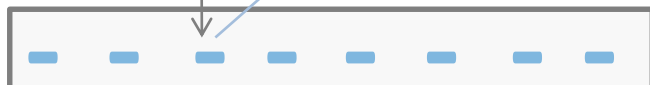


PHOTON

carries amount of

$$\text{Energy} = hf$$

gives ALL to ONE



ELECTRON

in

metal

$$\text{KE}_{\text{max}} = \frac{1}{2} m v_{\text{max}}^2$$

=

$$\text{KE}_{\text{max}} = hf - hf_0$$

for surface electrons occurs with

photoelectric emission

for

$$W_0 = hf_0$$

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type determines



PHOTON

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gives ALL to ONE



ELECTRON

in

metal

$$KE_{\max} = \frac{1}{2} m v_{\max}^2$$

=

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for surface electrons occurs with

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for

$$W_0 = hf_0$$

needs $\geq$

type determines

energy photon gives

energy e^- needs to
break free from Zn

energy photon gives
 $=6,91 \times 10^{-19} \text{ J}$

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energy photon gives
 $=6,91 \times 10^{-19} \text{ J}$

Zn's work function, W_0
 $=6,91 \times 10^{-19} \text{ J}$

energy photon gives

energy e^-
needs to
break free

e^- 's
kinetic
energy

$$E = hf$$

$$W_0 = hf_0$$

KE

$$E = hf$$

$$W_0 = hf_0$$

KE

$$E = hf$$

$$W_0 = hf_0$$

KE

Metal	λ_0 (nm)	f_0 (Hz)	Movie
Pt	196	$1,53 \times 10^{15}$	
Cu	263	$1,14 \times 10^{15}$	
Zn	289	$1,04 \times 10^{15}$	
Ca	427	$7,03 \times 10^{14}$	
Na	539	$5,57 \times 10^{14}$	

Na's W_0

Na's W_0

$$= 3,38 \times 10^{-19} \text{ J}$$

Na's W_0

$$= 3,38 \times 10^{-19} \text{ J}$$

Zn's W_0

$$= 6,91 \times 10^{-19} \text{ J}$$

Question 2

How much energy does each photon of UV light of frequency $1,5 \times 10^{15}$ Hz have?

Solution

$$E = hf$$

$$= 6,63 \times 10^{-34} \text{ J}\cdot\text{s} \times 1,5 \times 10^{15} \text{ Hz}$$

$$= 6,63 \times 10^{-34} \text{ J}\cdot\cancel{\text{s}} \times 1,5 \times 10^{15} \cancel{\text{s}}^{-1}$$

$$= 9,95 \times 10^{-19} \text{ J}$$

energy e^- needs to
break free from Zn
 $=6,91 \times 10^{-19} \text{ J}$

energy photon gives
 $=9,95 \times 10^{-19} \text{ J}$

energy e^- needs to
break free from Zn
 $=6,91 \times 10^{-19} \text{ J}$

energy photon gives

energy e^- needs to
break free from metal

e^- 's
kinetic
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$$E=hf$$

energy e^- needs to
break free from metal

e^- 's
kinetic
energy

$$E=hf$$

$$W_0=hf_0$$

e^- 's
kinetic
energy

$$E=hf$$

$$W_0=hf_0$$

$$KE = E - W_0$$
$$hf - hf_0$$

Question 3

How much kinetic energy do electrons emitted from the surface of zinc have when light of frequency $1,5 \times 10^{15}$ Hz is incident on the zinc?

Solution

$$\begin{aligned} KE &= E - W_0 \\ &= 9,95 \times 10^{-19} \text{ J} - 6,91 \times 10^{-19} \text{ J} \\ &= 3,03 \times 10^{-19} \text{ J} \end{aligned}$$

$$E=hf$$

$$=9,95 \times 10^{-19} \text{ J}$$

$$E=hf$$
$$=9,95 \times 10^{-19} \text{ J}$$

$$W_0=hf_0$$
$$=6,91 \times 10^{-19} \text{ J}$$

e^- 's
kinetic
energy

$$E=hf$$
$$=9,95 \times 10^{-19} \text{ J}$$

$$W_0=hf_0$$
$$=6,91 \times 10^{-19} \text{ J}$$

$$KE = hf - W_0$$
$$= 3,03 \times 10^{-19} \text{ J}$$

Question 4

At what maximum speed are electrons emitted from the surface of zinc have when light of frequency $1,5 \times 10^{15}$ Hz is incident on the zinc?

Solution: v subject of formula

$$KE_{\max} = \frac{1}{2} m v_{\max}^2$$

$$KE_{\max} \times \frac{2}{m} = \frac{1}{2} m v_{\max}^2 \times \frac{2}{m}$$

$$\frac{2KE_{\max}}{m} = v_{\max}^2$$

$$\sqrt{\frac{2KE_{\max}}{m}} = \sqrt{v_{\max}^2}$$

$$\sqrt{\frac{2KE_{\max}}{m}} = v$$

$$v_{\max} = \sqrt{\frac{2KE_{\max}}{m}}$$

Solution: Known values

$$v_{max} = \sqrt{\frac{2KE_{max}}{m}}$$

Known: m of $1 e^- = 9,11 \times 10^{-31} \text{ kg}$

Known: $3,03 \times 10^{-19} \text{ J}$ (from Question 3)

Solution

$$v_{max} = \sqrt{\frac{2(3,03 \times 10^{-19})}{9,11 \times 10^{-31}}}$$

$$v_{max} = 815\,599 \text{ m} \cdot \text{s}^{-1}$$

$$v_{max} = 816\,000 \text{ m} \cdot \text{s}^{-1}$$

Question 4

Light of a certain frequency is incident on a piece of sodium. The maximum kinetic energy of the emitted electrons is $1,07 \times 10^{-20}$ J. What is the frequency of the incident light?

Solution: making f the subject of the formula

$$KE_{\max} = E - W_0$$

$$KE_{\max} = hf - hf_0$$

$$KE_{\max} + hf_0 = hf - hf_0 + hf_0$$

$$KE_{\max} + hf_0 = hf$$

$$hf = KE_{\max} + hf_0$$

$$\underline{hf} = \underline{KE_{\max} + hf_0}$$

$$\overset{h}{f} = \frac{\overset{h}{KE_{\max}} + hf_0}{h}$$

Solution: Known values

$$f = \frac{KE_{\max} + hf_0}{h}$$

$$KE_{\max} = 1,07 \times 10^{-20} \text{ J}$$

$$\text{Na's } f_0 = 5,57 \times 10^{14} \text{ Hz}$$

$$h = 6,63 \times 10^{-34} \text{ J}\cdot\text{s}$$

Solution: Known values

$$f = \frac{1,07 \times 10^{-20} + 6,63 \times 10^{-34} \cdot 5,57 \times 10^{14}}{6,63 \times 10^{-34}}$$

$$f = 5,73 \times 10^{14} \text{ Hz}$$

energy photon gives

energy e^-
needs to
break free

e^- 's
kinetic
energy

$$E = hf$$

$$W_0 = hf_0$$

KE

$$E = hf$$

$$W_0 = hf_0$$

KE

$$E = hf$$

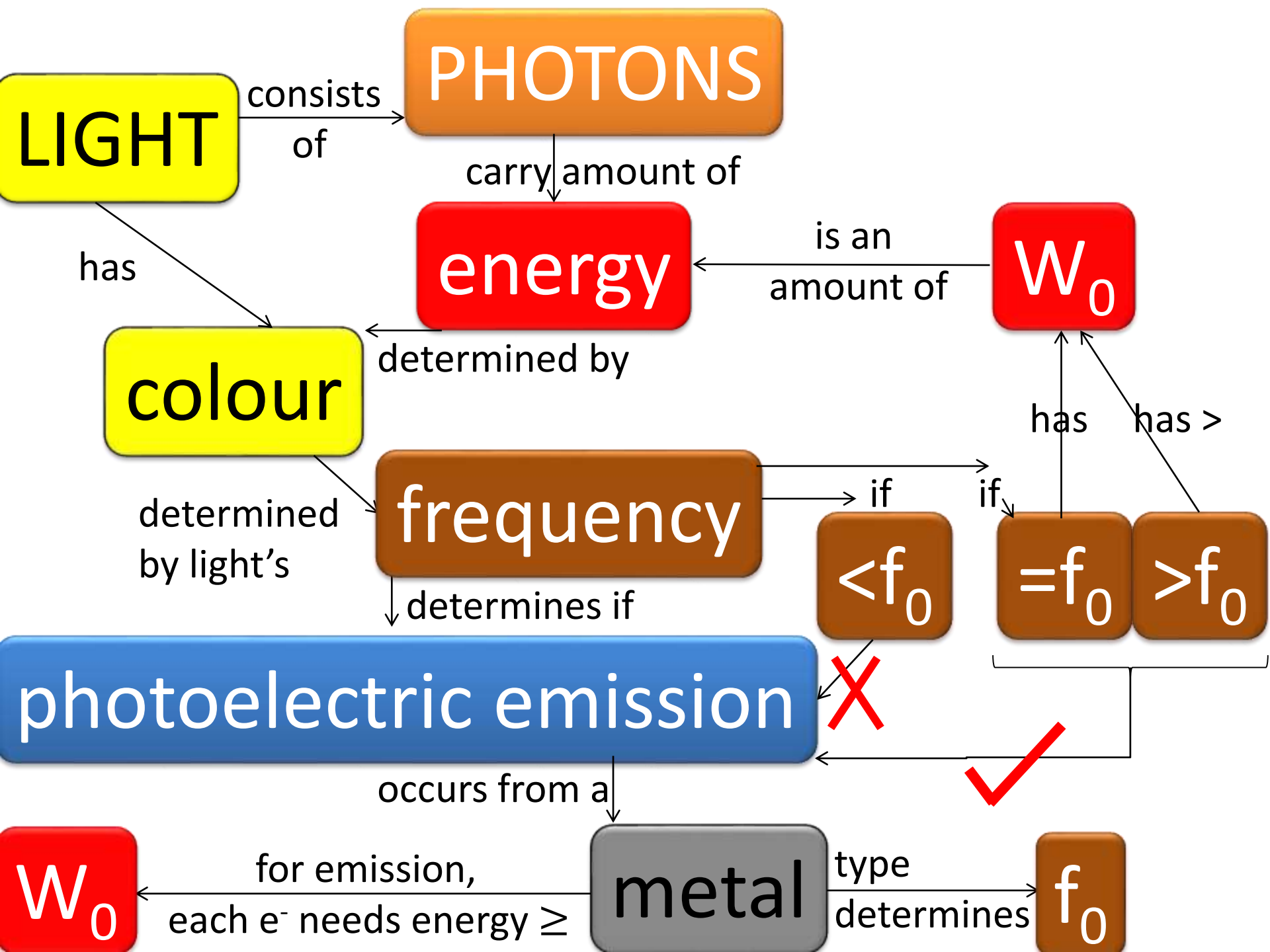
$$W_0 = hf_0$$

KE

$$E = hf$$

$$W_0 = hf_0$$

KE



of

LIGHT

consists of

PHOTONS

has

intensity

determined by

emission rate

affects rate that

photoelectric emission

occurs from a

metal

