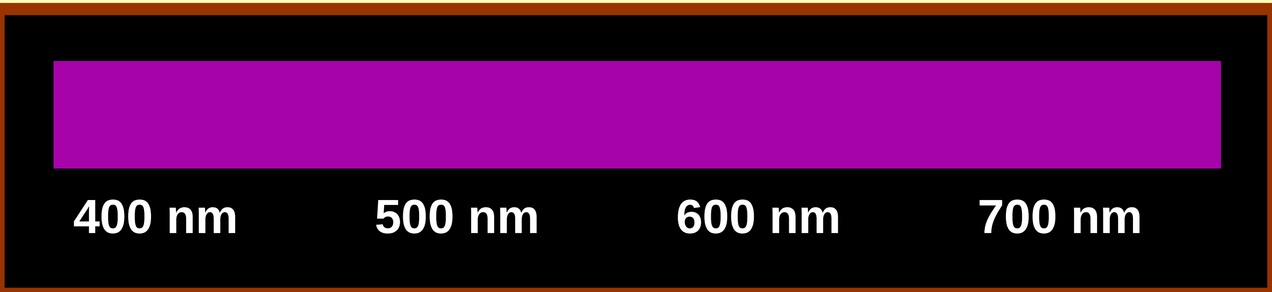
ConcepTest 27.1 Photons

Which has more energy, a photon of:

1) red light
2) yellow light
3) green light
4) blue light
5) all have the same energy



ConcepTest 27.1 Photons

Which has more energy, a photon of:

1) red light
2) yellow light
3) green light
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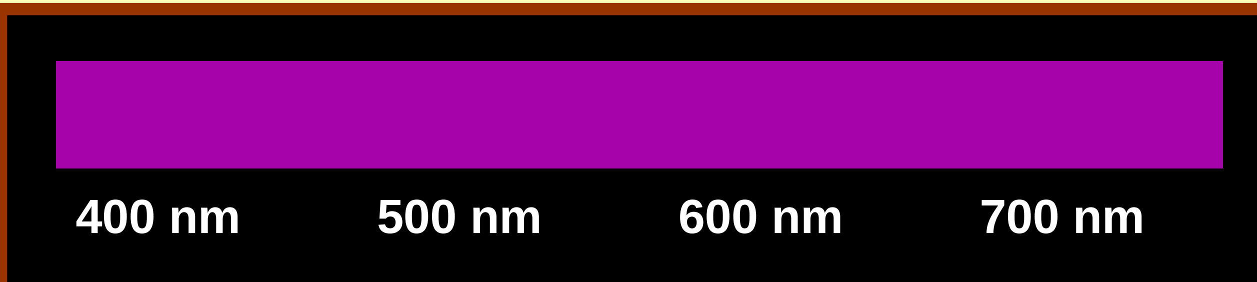
5) all have the same energy

$$E = hf$$

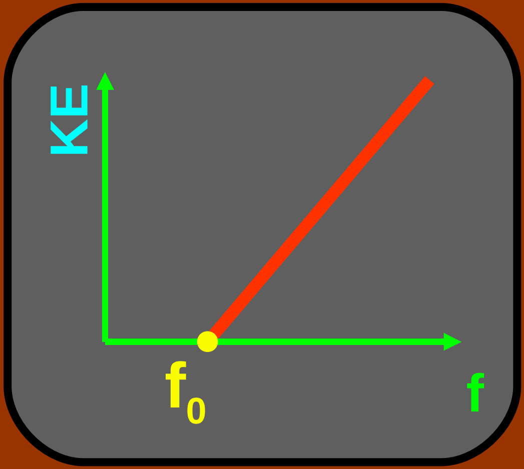


The photon with the **highest frequency** has the **most energy** because $E = hf = hc/\lambda$ (recall that $c = f\lambda$). So a **higher frequency** corresponds to a **lower wavelength**. The highest energy of the above choices is **blue**.

ConcepTest 27.2a Photoelectric Effect I

If the cutoff frequency for light in the photoelectric effect for metal B is greater than that of metal A. Which metal has a greater work function?

1) metal A
2) metal B
3) same for both
4) W_0 must be zero for one of the metals

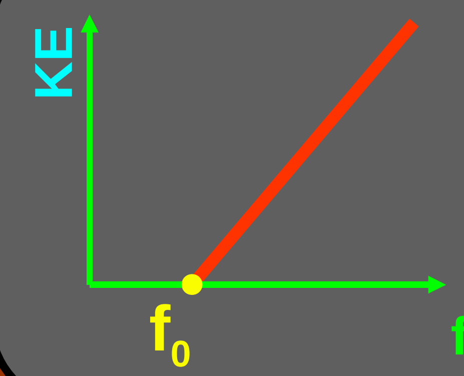


ConcepTest 27.2a Photoelectric Effect I

If the cutoff frequency for light in the photoelectric effect for metal B is greater than that of metal A. Which metal has a greater work function?

1) metal A
2) metal B
3) same for both
4) W_0 must be zero for one of the metals

A greater cutoff frequency means a higher energy is needed to knock out the electron. But this implies that the work function is greater, since the work function is defined as the minimum amount of energy needed to eject an electron.



Follow-up: What would you expect to happen to the work function of a metal if the metal was heated up?

ConcepTest 27.2b Photoelectric Effect II

A metal surface with a work function of W_0 = hc/550 nm is struck with blue light and electrons are released. If the blue light is replaced by red light of the same intensity, what is the result?

1) emitted electrons are more energetic
2) emitted electrons are less energetic
3) more electrons are emitted in a given time interval
4) fewer electrons are emitted in a given time interval
5) no electrons are emitted

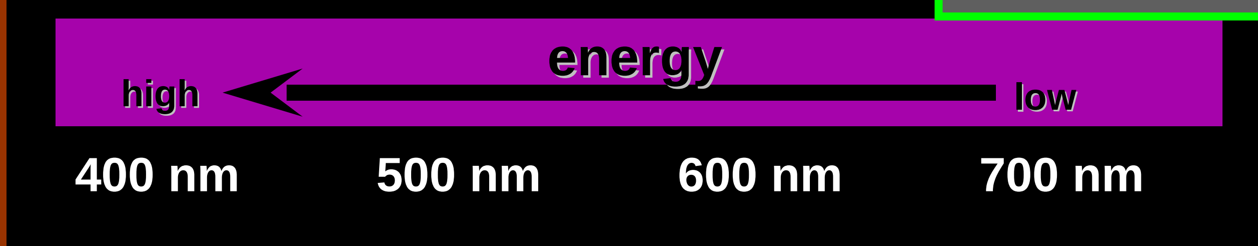
ConcepTest 27.2b Photoelectric Effect II

A metal surface with a work function of $W_0 = hc/550$ nm is struck with blue light and electrons are released. If the blue light is replaced by red light of the same intensity, what is the result?

1) emitted electrons are more energetic
2) emitted electrons are less energetic
3) more electrons are emitted in a given time interval
4) fewer electrons are emitted in a given time interval
5) no electrons are emitted

Red light has a wavelength of about 700 nm. The cutoff wavelength is 550 nm (yellow light), which is the maximum wavelength to knock out electrons. Thus, no electrons are knocked out.

$E = hc/\lambda$



ConcepTest 27.2c Photoelectric Effect III

A metal surface is struck with light of λ = 400 nm, releasing a stream of electrons. If the 400 nm light is replaced by λ = 300 nm light of the same intensity, what is the result?

1) more electrons are emitted in a given time interval
2) fewer electrons are emitted in a given time interval
3) emitted electrons are more energetic
4) emitted electrons are less energetic
5) none of the above

ConcepTest 27.2c Photoelectric Effect III

A metal surface is struck with light of λ = 400 nm, releasing a stream of electrons. If the 400 nm light is replaced by λ = 300 nm light of the same intensity, what is the result?

1) more electrons are emitted in a given time interval
2) fewer electrons are emitted in a given time interval
3) emitted electrons are more energetic
4) emitted electrons are less energetic
5) none of the above

A **reduced wavelength** means a **higher frequency**, which in turn means a **higher energy**. So the emitted electrons will be ***more energetic***, since they are now being hit with higher energy photons.

Remember that $c = f\lambda$ and that $E = hf$

ConcepTest 27.2d Photoelectric Effect IV

A metal surface is struck with light of λ = 400 nm, releasing a stream of electrons. If the light intensity is increased (without changing λ), what is the result?

1) more electrons are emitted in a given time interval
2) fewer electrons are emitted in a given time interval
3) emitted electrons are more energetic
4) emitted electrons are less energetic
5) none of the above

ConcepTest 27.2d Photoelectric Effect IV

A metal surface is struck with light of λ = 400 nm, releasing a stream of electrons. If the light intensity is increased (without changing λ), what is the result?

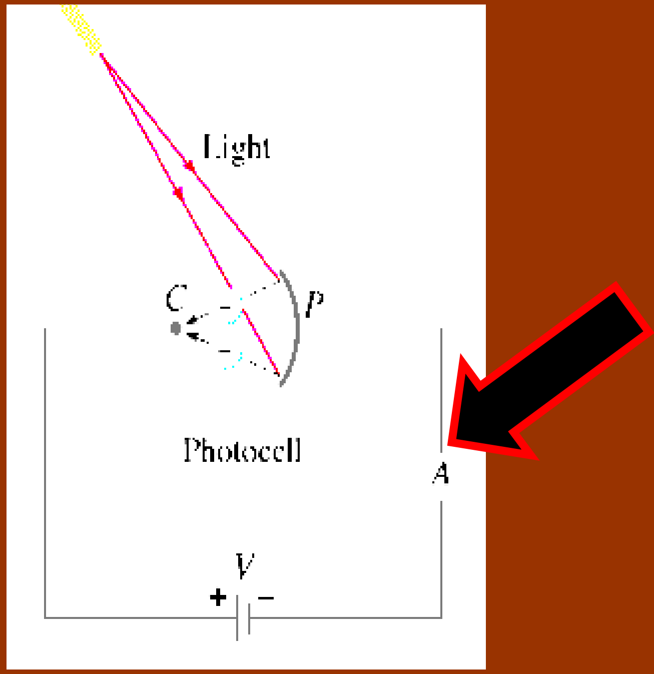
1) more electrons are emitted in a given time interval
2) fewer electrons are emitted in a given time interval
3) emitted electrons are more energetic
4) emitted electrons are less energetic
5) none of the above

A higher intensity means a more photons, which in turn means more electrons. On average, each photon knocks out one electron.

ConcepTest 27.2e Photoelectric Effect V

A photocell is illuminated with light with a frequency above the cutoff frequency. The **magnitude of the current** produced depends on:

1) wavelength of the light
2) intensity of the light
3) frequency of the light
4) all of the above
5) none of the above



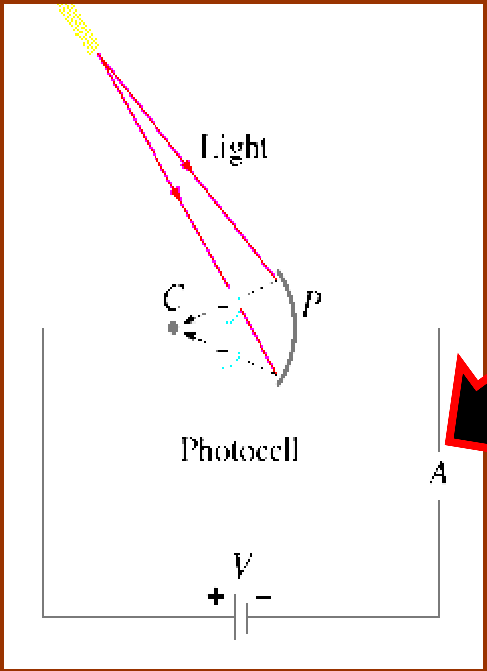
ConcepTest 27.2e Photoelectric Effect V

A photocell is illuminated with light with a frequency above the cutoff frequency. The magnitude of the current produced depends on:

1) wavelength of the light
2) intensity of the light
3) frequency of the light
4) all of the above
5) none of the above

Each photon can only knock out one electron. So to increase the current, we would have to knock out **more electrons**, which means we need **more photons**, which means we need a **greater intensity**!

Changing the **frequency** or **wavelength** will change the **energy** of each electron, but we are interested in the **number of electrons** in this case.



ConcepTest 27.3a Wave-Particle Duality I

The speed of proton A is larger than the speed of proton B. Which one has the longer wavelength?

1) proton A
2) proton B
3) both the same
4) neither has a wavelength

ConcepTest 27.3a Wave-Particle Duality I

The speed of proton A is larger than the speed of proton B. Which one has the longer wavelength?

1) proton A
2) proton B
3) both the same
4) neither has a wavelength

Remember that $\lambda = h/mv$ so the proton with the smaller velocity will have the longer wavelength.

ConcepTest 27.3b Wave-Particle Duality II

An **electron** and a **proton** have the **same speed**. Which has the **longer** wavelength?

1) electron
2) proton
3) both the same
4) neither has a wavelength

ConcepTest 27.3b Wave-Particle Duality II

An **electron** and a **proton** have the **same speed**. Which has the **longer** wavelength?

1) electron
2) proton
3) both the same
4) neither has a wavelength

Remember that $\lambda = h/mv$ and the particles both have the same velocity, so the particle with the **smaller** mass will have the **longer** wavelength.

ConcepTest 27.3c Wave-Particle Duality III

An **electron** and a **proton** are accelerated through the **same voltage**. Which has the **longer** wavelength?

1) electron
2) proton
3) both the same
4) neither has a wavelength

ConcepTest 27.3c Wave-Particle Duality III

An **electron** and a **proton** are accelerated through the **same voltage**. Which has the **longer** wavelength?

1) electron
2) proton
3) both the same
4) neither has a wavelength

Because $PE_i = KE_f$ both particles will get the **same kinetic energy** ($= 1/2\, mv^2 = p^2/2m$). So the lighter particle (electron) gets the smaller momentum.

Because $\lambda = h/mv$ the particle with the **smaller** momentum will have the **longer** wavelength.

ConcepTest 27.3d Wave-Particle Duality IV

An electron and a proton have the same momentum. Which has the longer wavelength?

1) electron
2) proton
3) both the same
4) neither has a wavelength

ConcepTest 27.3d Wave-Particle Duality IV

An electron and a proton have the same momentum. Which has the longer wavelength?

1) electron
2) proton
3) both the same
4) neither has a wavelength

Remember that $\lambda = h/mv$ and $p = mv$, so if the particles have the same momentum, they will also have the same wavelength.

ConcepTest 27.4 Ionization

How much energy does it take to ionize a hydrogen atom in its ground state?

1) 0 eV
2) 13.6 eV
3) 41.2 eV
4) 54.4 eV
5) 108.8 eV

ConcepTest 27.4 Ionization

How much energy does it take to ionize a hydrogen atom in its ground state?

1) 0 eV
2) 13.6 eV
3) 41.2 eV
4) 54.4 eV
5) 108.8 eV

The energy of the ground state is the energy that binds the electron to the nucleus. Thus, an amount equal to this binding energy must be supplied in order to kick the electron out of the atom.

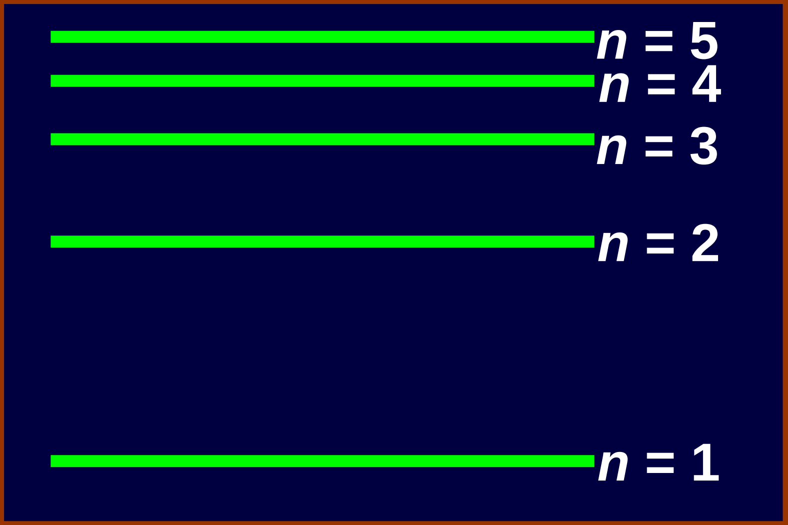
$$E_n = E_1 \frac{Z^2}{n^2}$$

Follow-up: How much energy does it take to change a He^{+} ion into a He^{++} ion? Keep in mind that $Z = 2$ for helium.

ConcepTest 27.5a Atomic Transitions I

For the possible transitions shown, for which transition will the electron **gain** the most energy?

1) 2 $\rightarrow$ 5
2) 5 $\rightarrow$ 3
3) 8 $\rightarrow$ 5
4) 4 $\rightarrow$ 7
5) 15 $\rightarrow$ 7



ConcepTest 27.5a Atomic Transitions I

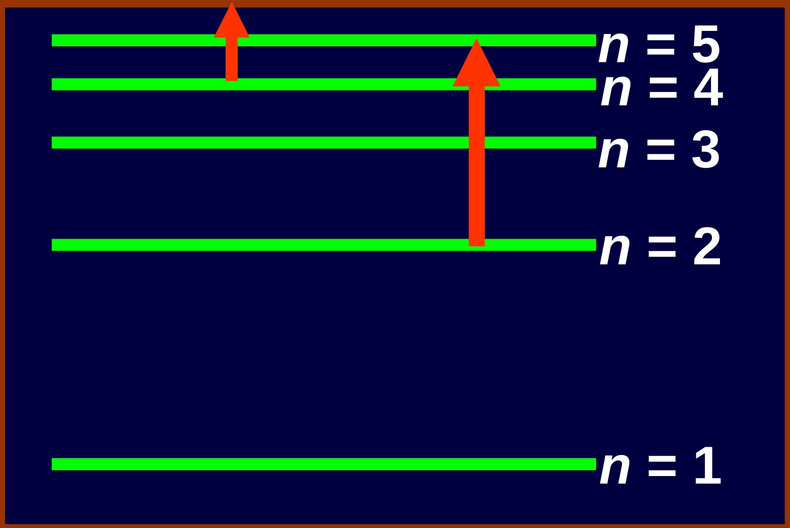
For the possible transitions shown, for which transition will the electron **gain** the most energy?

1) 2 → 5
2) 5 → 3
3) 8 → 5
4) 4 → 7
5) 15 → 7

The electron must go to a **higher** orbit (**higher** n) in order for the electron to gain energy.

Because of the $1/n^2$ dependence:

$$E_2 - E_5 > E_4 - E_7$$

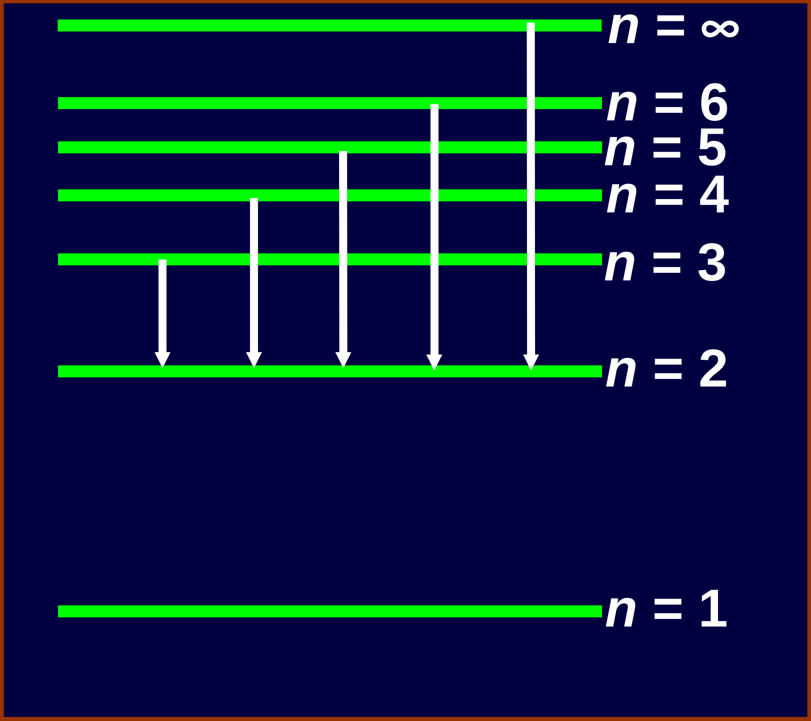


Follow-up: Which transition will emit the shortest wavelength photon?

ConcepTest 27.5b Atomic Transitions II

The Balmer series for hydrogen can be observed in the visible part of the spectrum. Which transition leads to the reddest line in the spectrum?

1) $3 \rightarrow 2$
2) $4 \rightarrow 2$
3) $5 \rightarrow 2$
4) $6 \rightarrow 2$
5) $\infty \rightarrow 2$

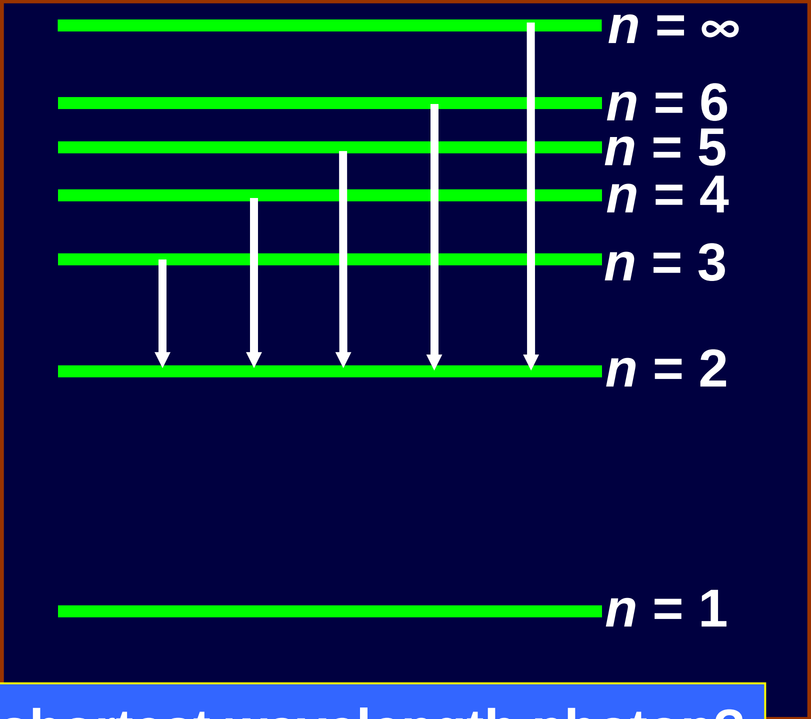


ConcepTest 27.5b Atomic Transitions II

The Balmer series for hydrogen can be observed in the visible part of the spectrum. Which transition leads to the **reddest** line in the spectrum?

1) 3 → 2
2) 4 → 2
3) 5 → 2
4) 6 → 2
5) ∞ → 2

The transition **3 → 2** has the **lowest energy** and thus the **lowest frequency** photon, which corresponds to the **longest wavelength** (and therefore the "**reddest**") line in the spectrum.

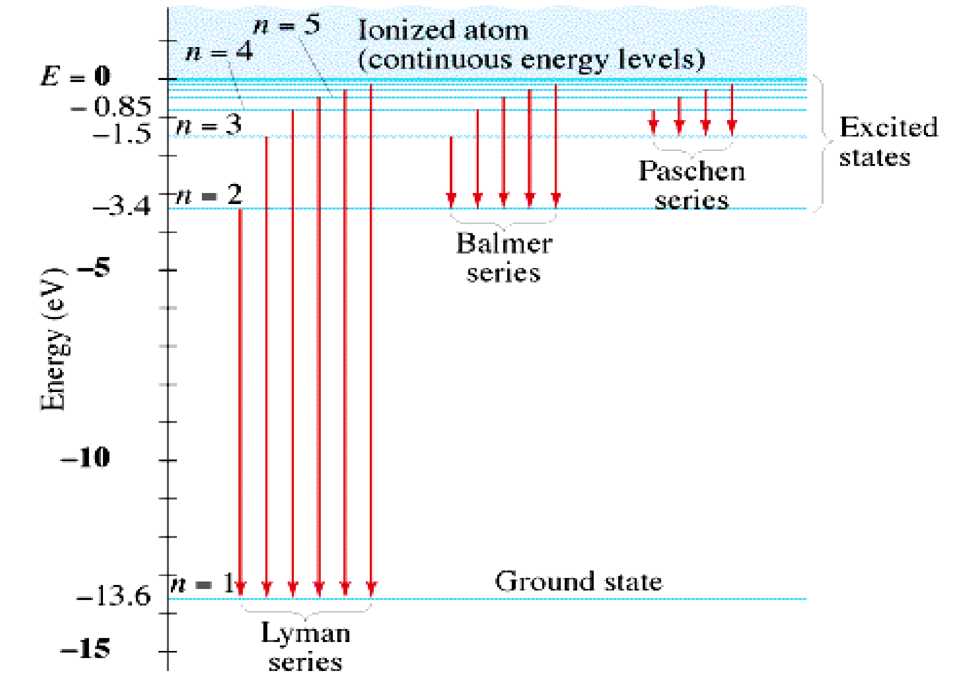


Follow-up: Which transition leads to the shortest wavelength photon?

ConcepTest 27.6 Balmer Series

When a broad spectrum of light passes through hydrogen gas at room temperature, absorption lines are observed that correspond only to the Balmer ($n_f = 2$) series. Why aren't other series observed?

1) they're there, but they're invisible
2) only the Balmer series can be excited at room temperature
3) the other series have been ionized
4) all the photons have been used up



ConcepTest 27.6 Balmer Series

When a broad spectrum of light passes through hydrogen gas at room temperature, absorption lines are observed that correspond only to the Balmer ($n_f = 2$) series. Why aren't other series observed?

1) they're there, but they're invisible

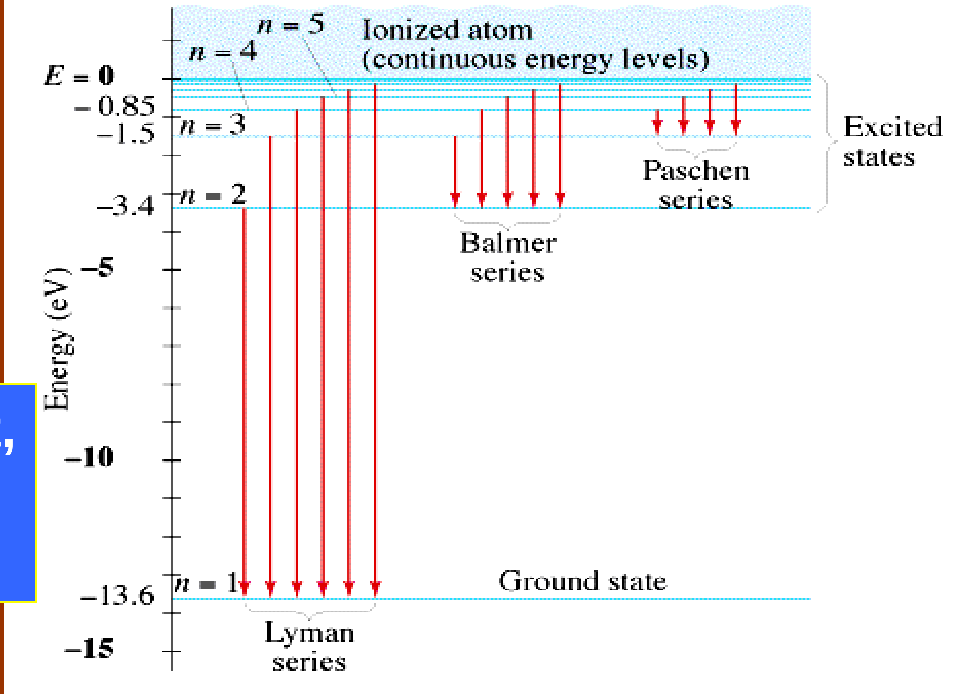
2) only the Balmer series can be excited at room temperature

3) the other series have been ionized

4) all the photons have been used up

The Balmer series is the only one that involves wavelengths in the visible part of the spectrum!

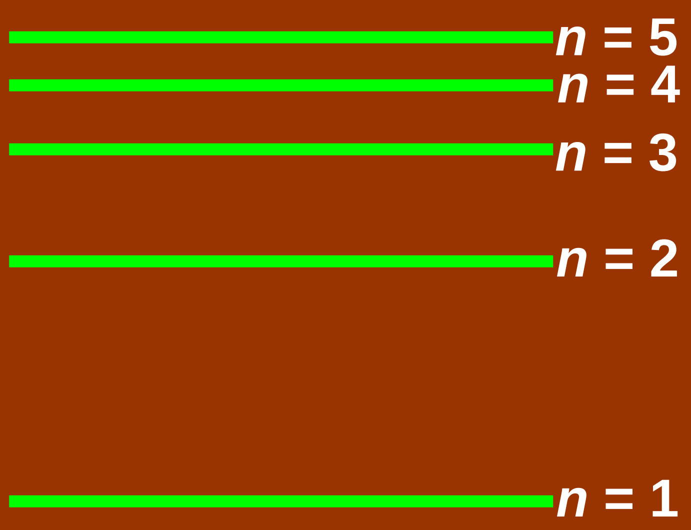
Follow-up: From the diagram at right, where in the EM spectrum is the Lyman series located?



ConcepTest 27.7a Energy Levels I

Suppose there is an atom that contains exactly five energy levels. How many different transitions are possible? (Count only one direction!)

1) 4
2) 5
3) 10
4) 20
5) many more than 20



ConcepTest 27.7a Energy Levels I

Suppose there is an atom that contains exactly **five** energy levels. How many different transitions are possible? (Count only one direction!)

1) 4
2) 5
3) 10
4) 20
5) many more than 20

Just count them! Transitions **upward**:

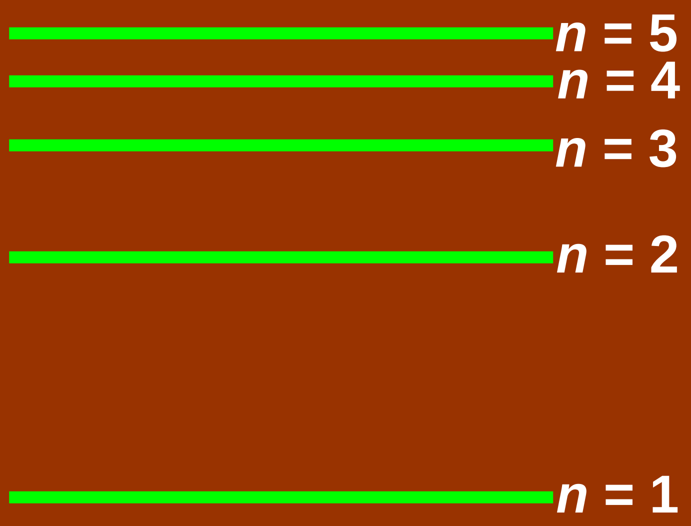
$n = 1 \rightarrow n = ?$ 4 transitions

$n = 2 \rightarrow n = ?$ 3 transitions

$n = 3 \rightarrow n = ?$ 2 transitions

$n = 4 \rightarrow n = ?$ 1 transition

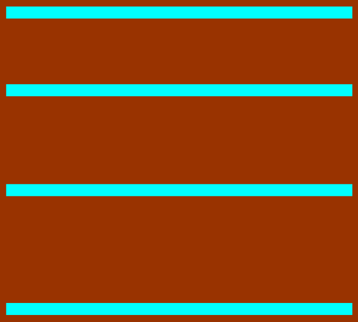
This gives a total of 10 possible ones.



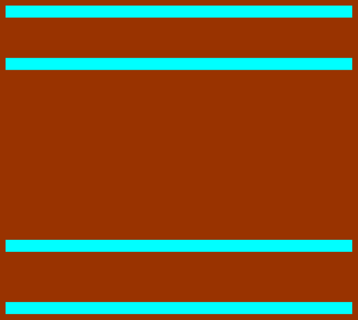
ConcepTest 27.7b Energy Levels II

The emission spectrum for the atoms of a gas is shown. Which of the energy level diagrams below corresponds to this spectrum?

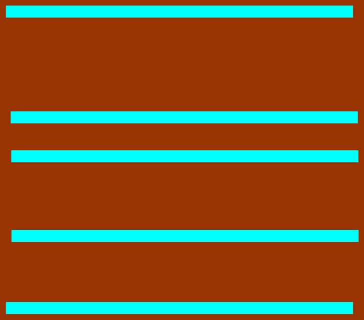
(1)



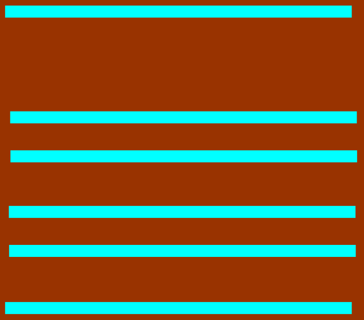
(2)



(3)



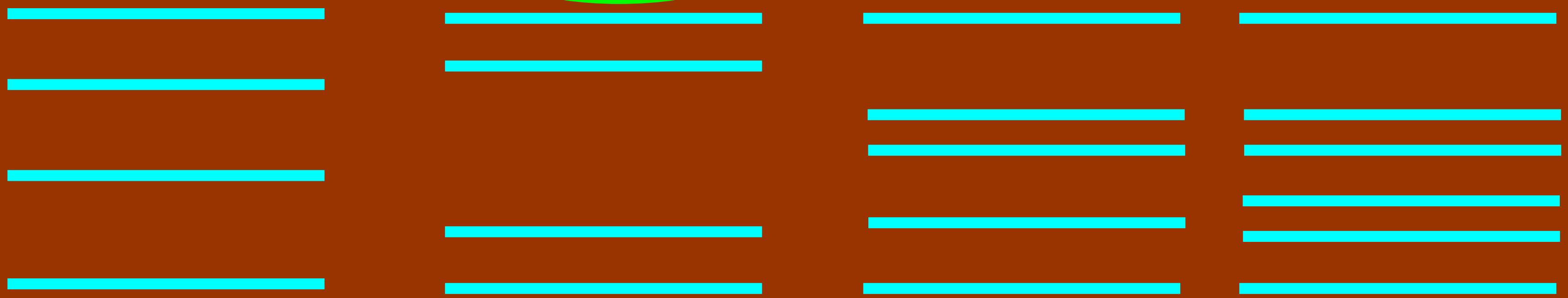
(4)



ConcepTest 27.7b Energy Levels II

The emission spectrum for the atoms of a gas is shown. Which of the energy level diagrams below corresponds to this spectrum?

(1) (2) (3) (4)



Each line in the spectrum corresponds to a *transition* between energy levels! Since there are 6 transitions shown, there must be 4 levels. The 2 transitions between the closely spaced levels have less energy, while the other 4 have larger energies.

ConcepTest 27.8 Rutherford Model

Suppose the Rutherford model was correct (instead of the Bohr model). What would the absorption spectrum of a hydrogen atom look like?

1) there would be no change
2) the absorption lines would be broader
3) it would be completely black
4) the absorption lines would be shifted
5) the absorption lines would be bright instead of dark

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In the Rutherford model, **all orbits are allowed** for the electrons. Thus, the atom would be able to absorb ***all*** wavelengths of light instead of only the specific ones allowed in the Bohr model.