- These slides contain animations, when the PowerPoint file is played
- The content gradually appears with clicks
- Questions appear before their answers

Green Chemistry and Living in the Desert

Sun

- What we do and don't want from it
- Energy from the sun (fossil fuels vs renewables)
- Light/matter interactions
- Infrared, heat, greenhouse effect
- Ultraviolet, sunburn, sunscreen, oxygen, ozone layer

Green Chemistry and Living in the Desert

Sun

What do we want from the sun?

Light to see
Light for plants to grow
Energy to power things
Warmth (in winter)

What don't we want from it?

Sun damage
Sun burn
Too much heat (summer)
Sun in eyes while driving?

These processes result from the different ways that sunlight interacts with matter

Green Chemistry and Living in the Desert

Sun

Did you know?/have you noticed:

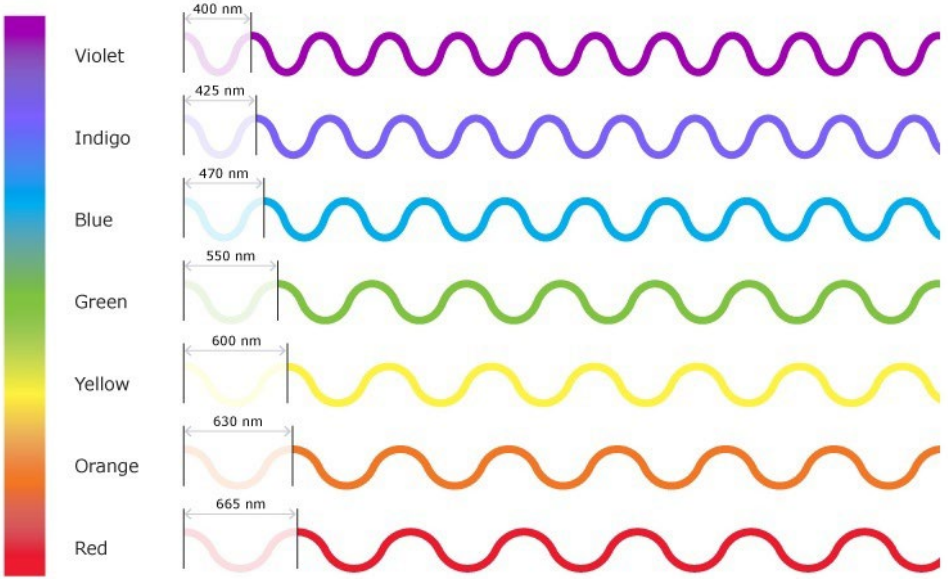
You can sit in the sun behind a window and feel just as hot as if the window was not there, yet not get sunburned

On a somewhat cloudy day you can feel relief from the heat of the sun, yet you can still easily be sunburned

What is going on in those situations?

Light Matter Interactions

Considering light as a wave, we can classify light by its wavelength:

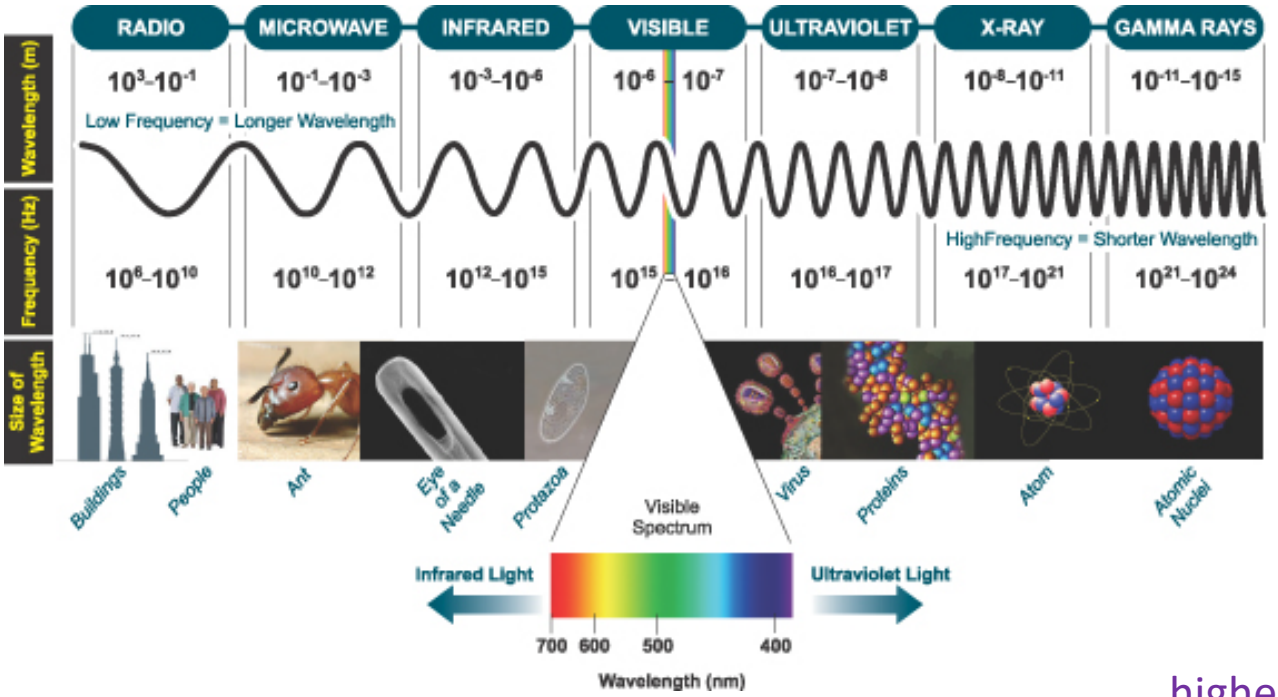


higher energy

But this is just what we can see!

Light Matter Interactions

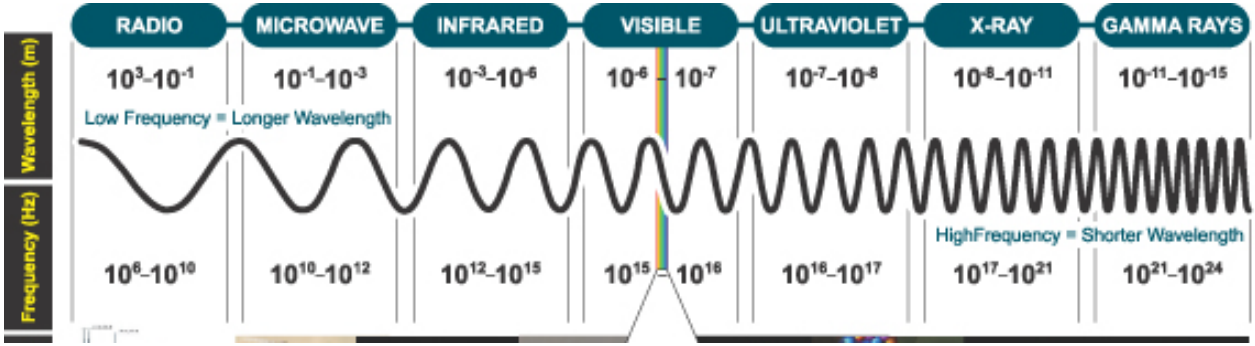
There is a whole range light types at both higher and lower wavelengths:



higher energy

http://www.astro.virginia.edu/~rsl4v/PSC/light.html

Light Matter Interactions



What effects does each type (wavelength) of light have on molecules?:

a) X-rays
b) Ultraviolet radiation
c) Visible light
d) Infra red light
e) Microwaves
f) Radiowaves

http://www.astro.virginia.edu/~rsl4v/PSC/light.html

Light Matter Interactions

a) X-rays	Promotion of electrons from low-lying atomic orbitals
b) Ultraviolet radiation	Promotion of electrons from molecular orbitals to higher energy molecular orbitals
c) Visible light	Same as UV
d) Infrared light	Excites bond vibrations in molecules
e) Microwaves	Excites rotations in molecules
f) Radiowaves	Excites nuclear spins in atoms

http://www.astro.virginia.edu/~rsl4v/PSC/light.html

Light Matter Interactions

- Feeling hot from the sun and getting sunburned have different causes
- The earlier examples highlight this:

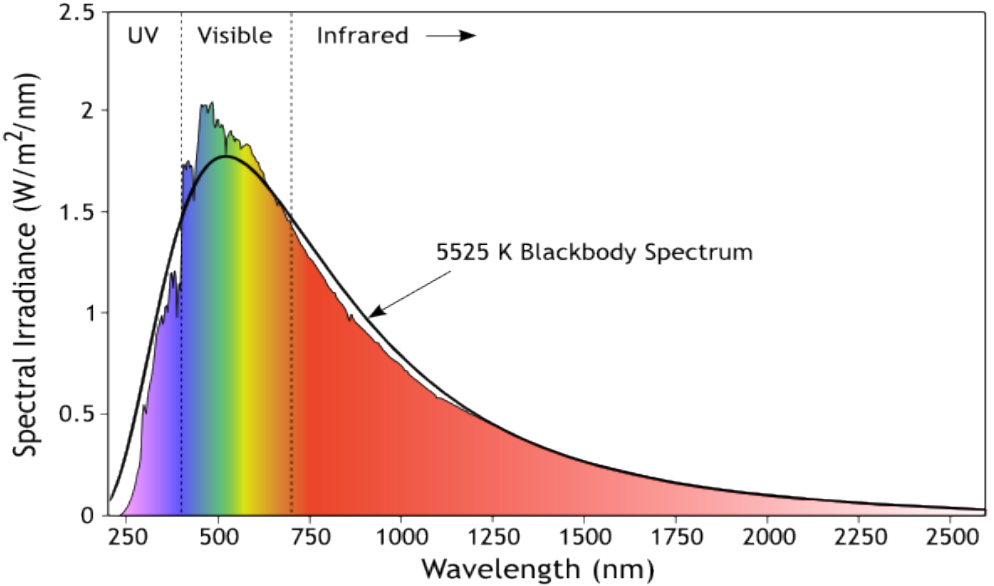
You can sit in the sun behind a window and feel just as hot as if the window was not there, yet not get sunburned

Glass absorbs the UV radiation that causes sunburn yet allows the longer wavelengths (visible and some IR wavelengths) to pass. So, we still feel plenty hot due to the IR radiation.

On a somewhat cloudy day you can feel relief from the heat of the sun, yet you can still easily be sunburned

Clouds (water) absorb and scatter IR radiation more effectively than they do UV. So, we may feel cooler because less IR is striking us, however the penetrating UV can still easily cause sunburn.

Light from the Sun



Sunlight energy reaching the earth's surface:

3-5%	Ultraviolet
42-43%	Visible
52-55%	Infrared

Wikipedia – "Sunlight"

Light Matter Interactions

a) X-rays	Promotion of electrons from low-lying atomic orbitals
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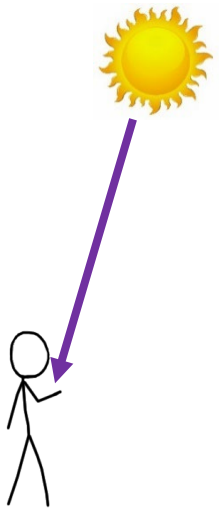
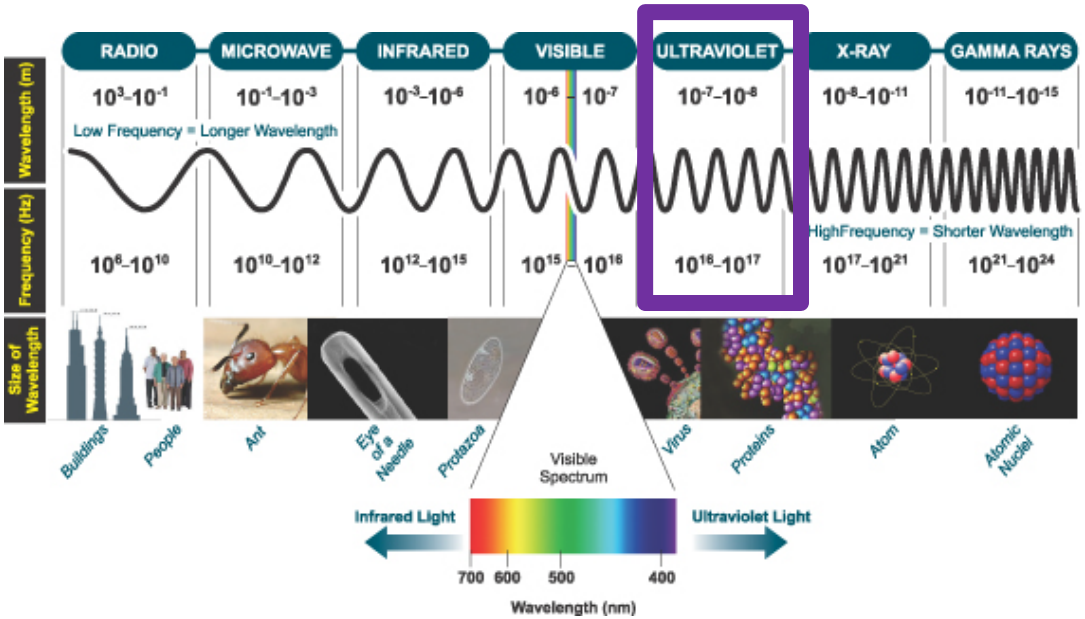
Light Matter Interactions - UV

Some important cases related to life, health, and sustainability



interaction with oxygen
interaction with ozone
vitamin D production
sunburn, DNA damage
melanin production
sunscreens

Light Matter Interactions - UV



http://www.astro.virginia.edu/~rsl4v/PSC/light.html

Light Matter Interactions - UV

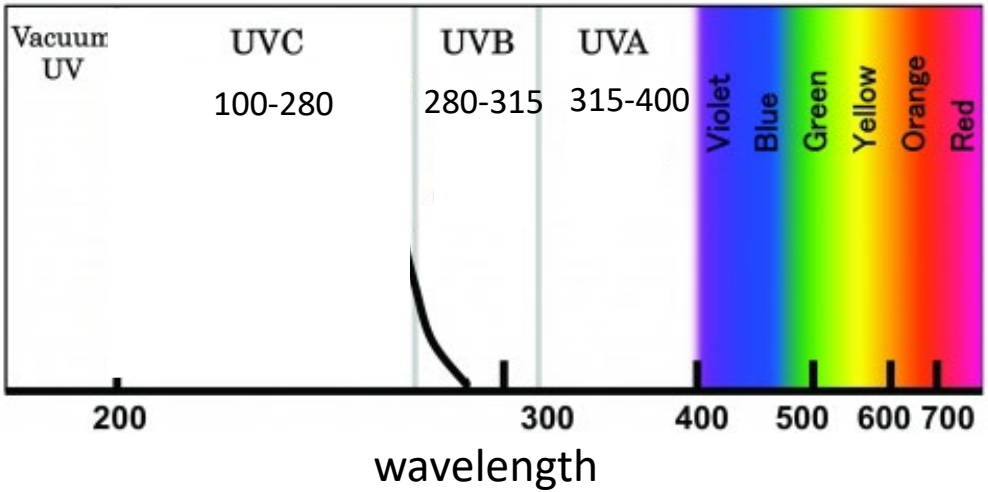
What does this mean?

Light Matter Interactions - UV

UVA, UVB…What about UVC?

Which is more dangerous UVA, UVB, or UVC?

Light Matter Interactions - UV



Which has more energy UVA, UVB, or UVC?

Shorter wavelength = higher energy (e.g. energy of UVB > UVA)

Generally higher energy -> greater damage

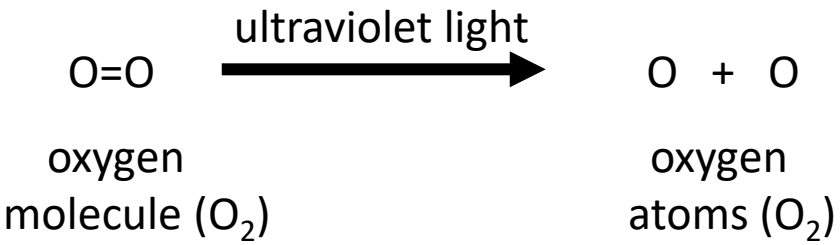
https://www.compoundsemiconductor.net/article/91348-building-brighter-and-cheaper-uv-leds.html

Light Matter Interactions - UV

b) Ultraviolet radiation	Promotion of electrons from molecular orbitals to higher energy molecular orbitals

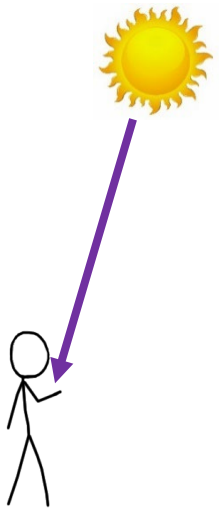
This can lead to the breaking of covalent bonds in molecules

For example:



Light Matter Interactions - UV

Some important cases related to life, health, and sustainability



interaction with oxygen

interaction with ozone

vitamin D production

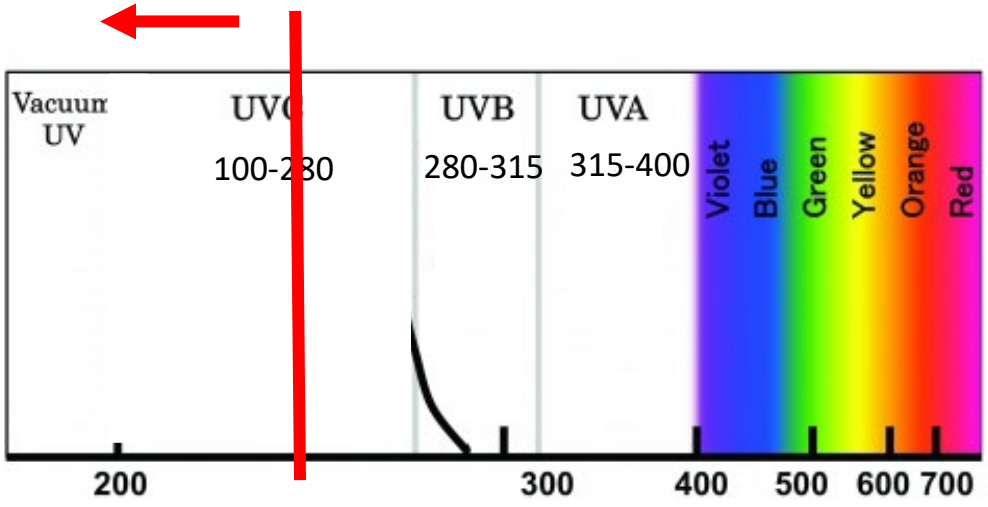
melanin production

sunburn, DNA damage

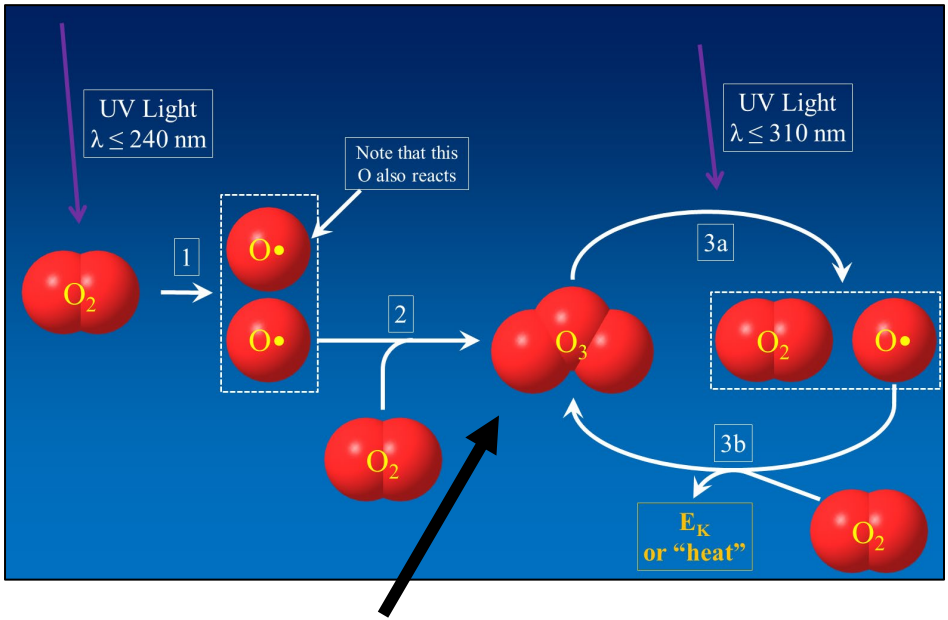
sunscreens

Light Matter Interactions - UV

- Photons with wavelength 240 nm or less have sufficient energy to do this (= UVC)



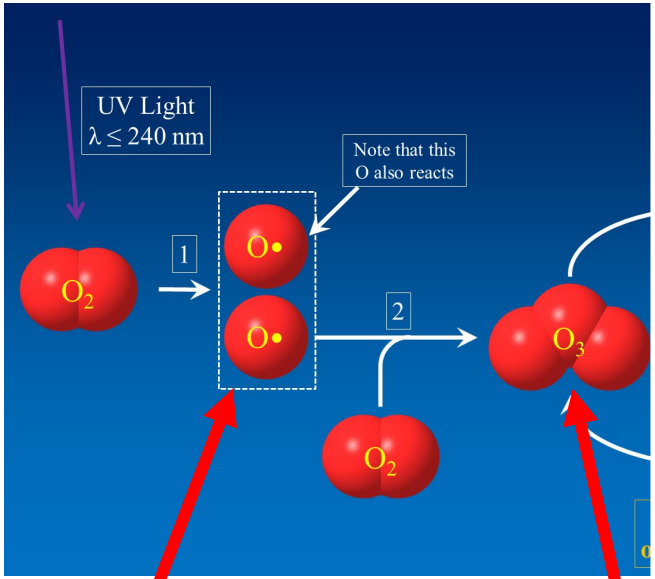
UV light vs Oxygen



What is this compound?

What happens when ozone (O_3) absorbs UV light?

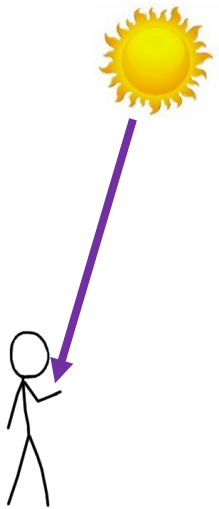
UV light vs Oxygen



- Oxygen atoms are high-energy, reactive species
- They react rapidly with O_2 to form O_3 (ozone)

Light Matter Interactions - UV

Some important cases related to life, health, and sustainability



interaction with oxygen

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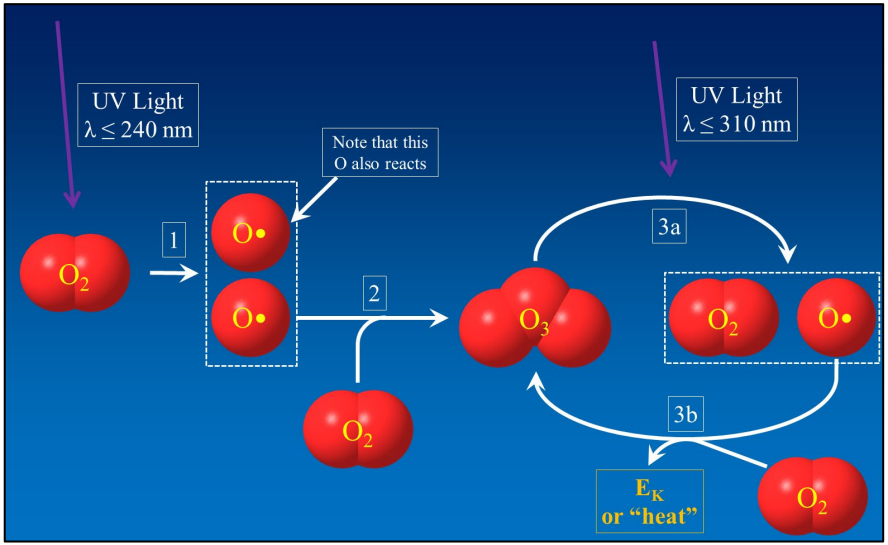
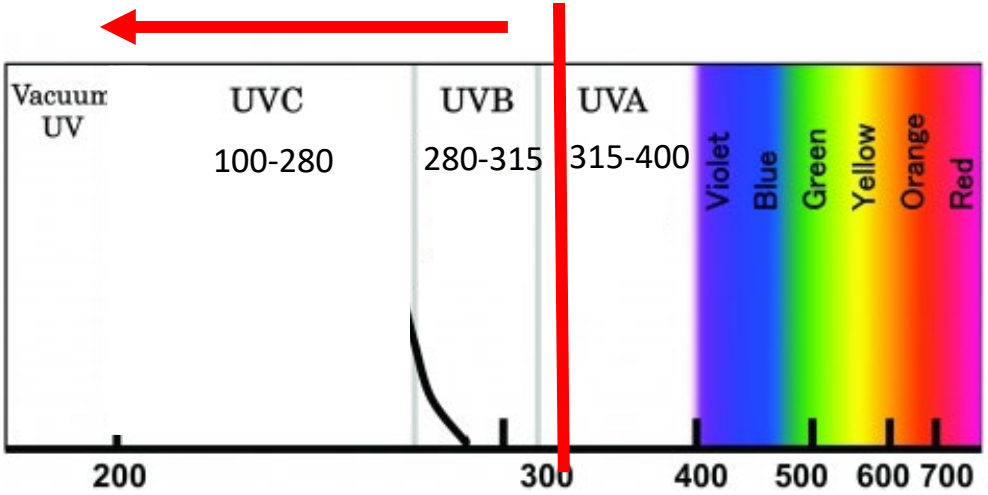
Chapman Cycle



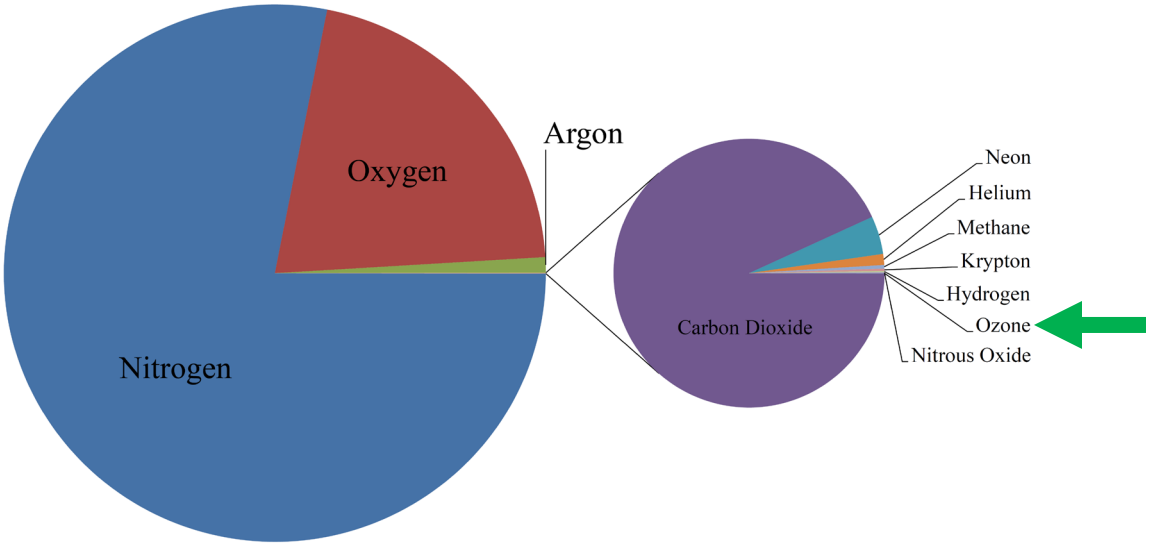
- Ozone also absorbs UV light (a longer wavelength is sufficient) and can split back into O_2 and O
- Those can then recombine to form O_3, the excess energy manifests as kinetic energy of the O_3 molecule (ultimately as heat)

O_2/O_3 Cycle

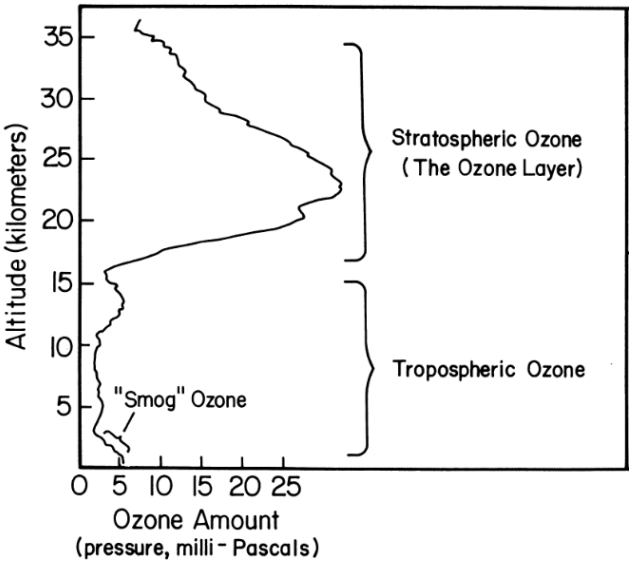
- Photons with wavelength 310 nm or less have sufficient energy to be absorbed by O_3 do this (= UVB, UVC)



Atmosphere Composition



The Ozone Layer



http://www.ozonelayer.noaa.gov/science/basics.htm

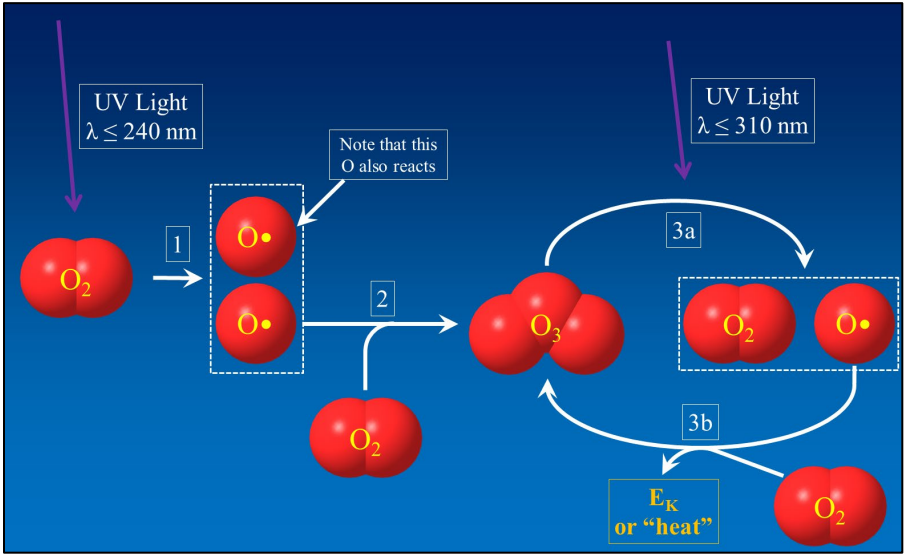
- As the second most abundant gas in the atmosphere O_2 is present in high concentration throughout
- However, ozone is concentrated only at higher altitudes in the stratosphere

About 12% of the ozone layer is generated by sunlight every day

What does that mean!?

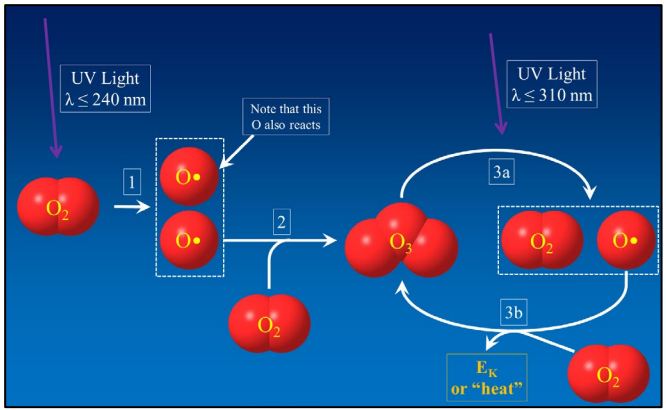
https://skincareclub.wordpress.com/2011/02/25/uva-uvb-uvc-rays/

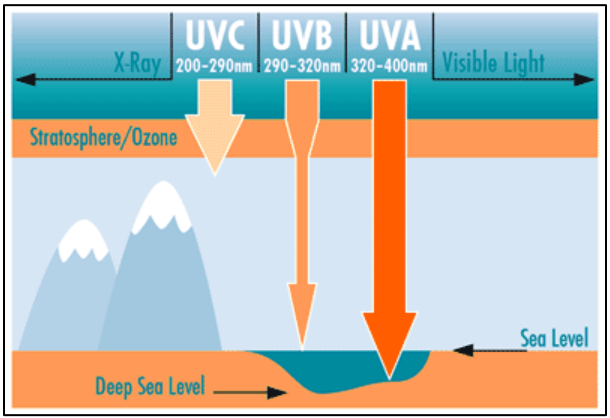
Chapman Cycle



- These reactions absorb most of the UV radiation (at those wavelengths) coming from the sun
- Overall, the energy from UV light is converted into heat by these processes

Chapman Cycle



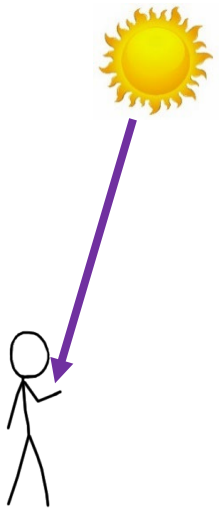


- Between the O_2 cleavage and the O_2/O_3 cycle, effectively all of the UVC and much of the UVB from the sun is absorbed by the atmosphere

https://skincareclub.wordpress.com/2011/02/25/uva-uvb-uvc-rays/

Light Matter Interactions - UV

Some important cases related to life, health, and sustainability



interaction with oxygen

interaction with ozone

vitamin D production

sunburn, DNA damage

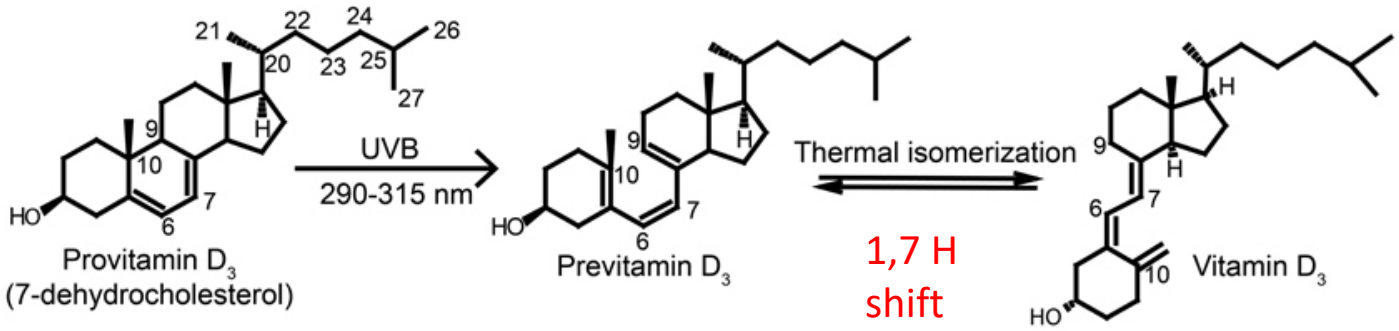
melanin production

sunscreens

Vitamin D

"Vitamin D comes from sunlight" As a chemist what do you think about that statement?

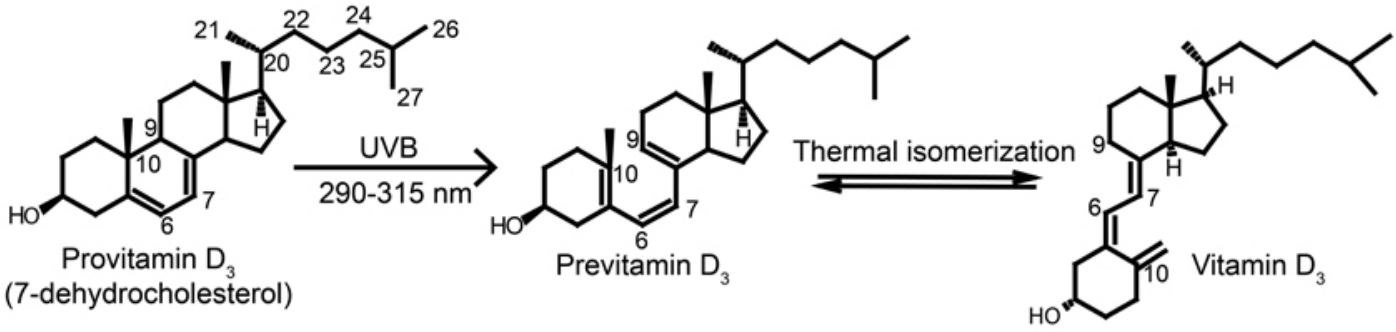
- Not the best way to express this – vitamin D is a compound, light is required to convert provitamin D into vitamin D:



(present in relatively large quantities in the skin)

https://en.wikipedia.org/wiki/Cholecalciferol

Vitamin D



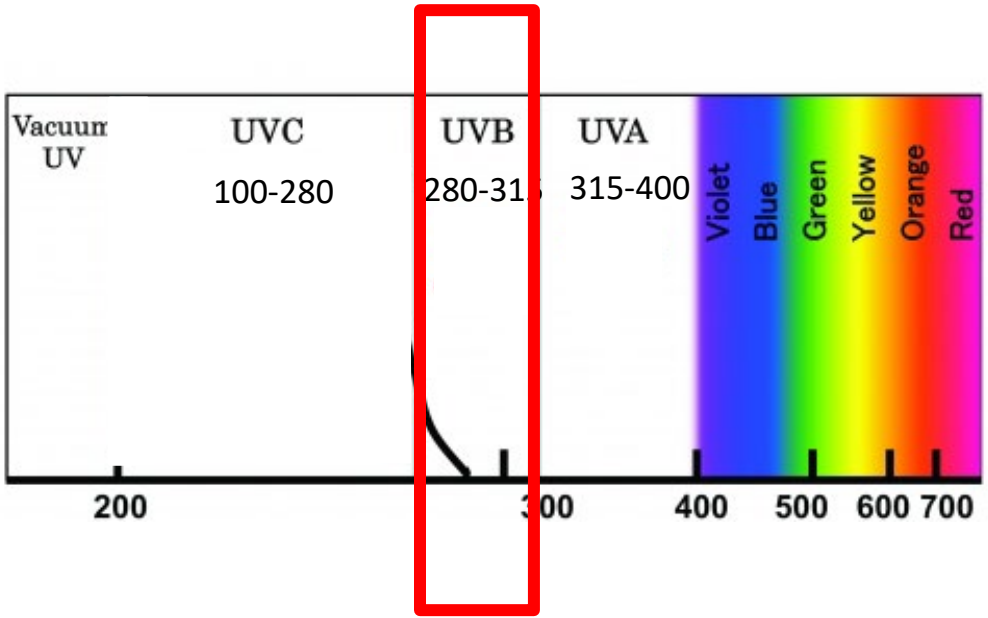
- UV light 270-300 nm is needed for this reaction
- That corresponds to UVB

What are the issues concerning getting enough vitamin D?

Sunburn/Sun Damage!

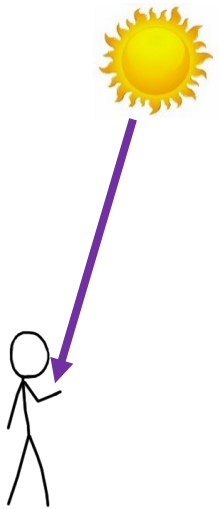
https://en.wikipedia.org/wiki/Cholecalciferol

Vitamin D Formation



Light Matter Interactions - UV

Some important cases related to life, health, and sustainability



interaction with oxygen
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sunscreens

“Sunburn”

- Caused by the small amount of UVB that reaches us at ground level
- UV absorption by various types of molecules can lead to formation of reactive molecules that destroy tissue

  e.g.

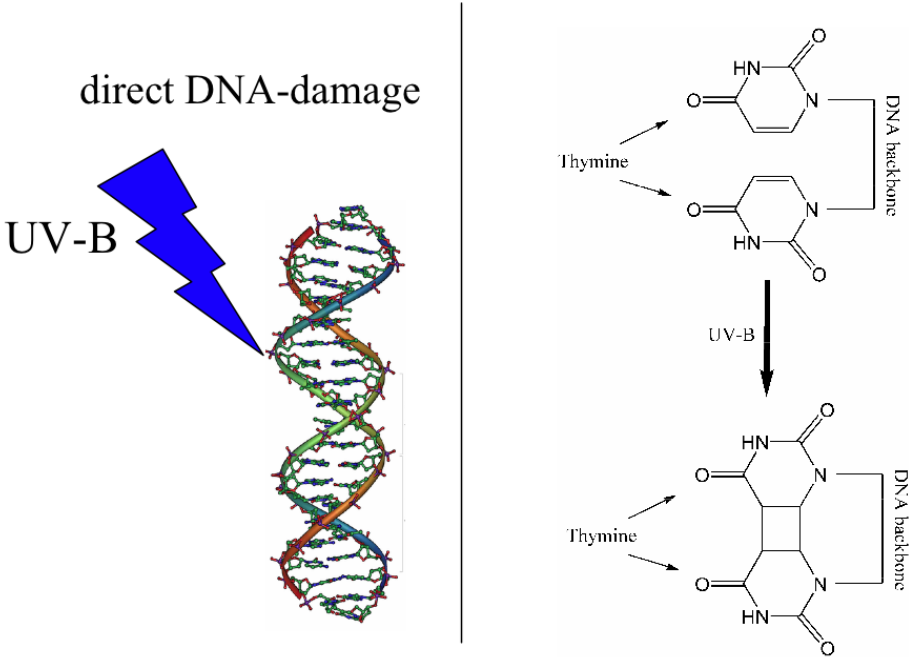
  $^{\cdot}OH$ = hydroxyl radical

- There is also a specific reaction that leads directly to DNA damage

https://en.wikipedia.org/wiki/Cholecalciferol

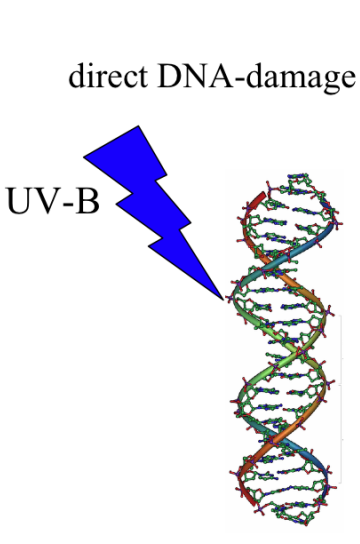
“Sunburn”

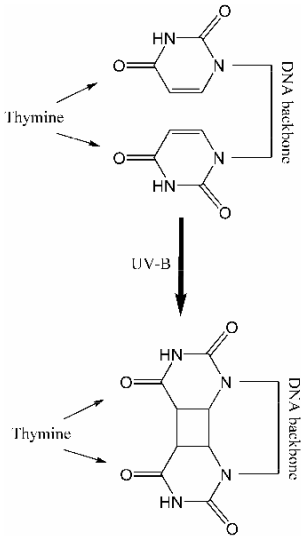
- Caused by the small amount of UVB that reaches us at ground level



“Sunburn”

- There are biological processes that repair this, but if not fixed can lead to mutations.

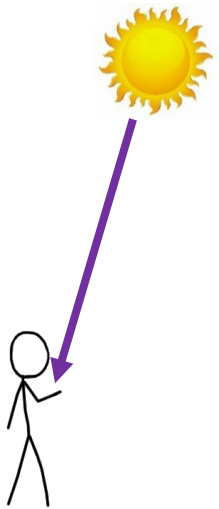




- While not causing sunburn, UVA is also somewhat damaging to the skin contributing to long-term effects such as premature skin aging and skin cancer
- Modern sunscreens also block UVA, hence “broad spectrum” because they block UVA and UVB.

Light Matter Interactions - UV

Some important cases related to life, health, and sustainability



interaction with oxygen

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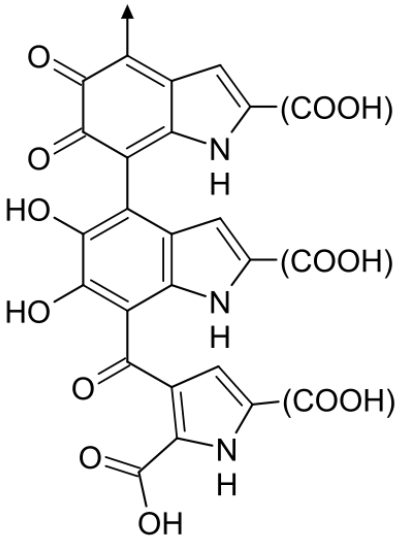
Melanin



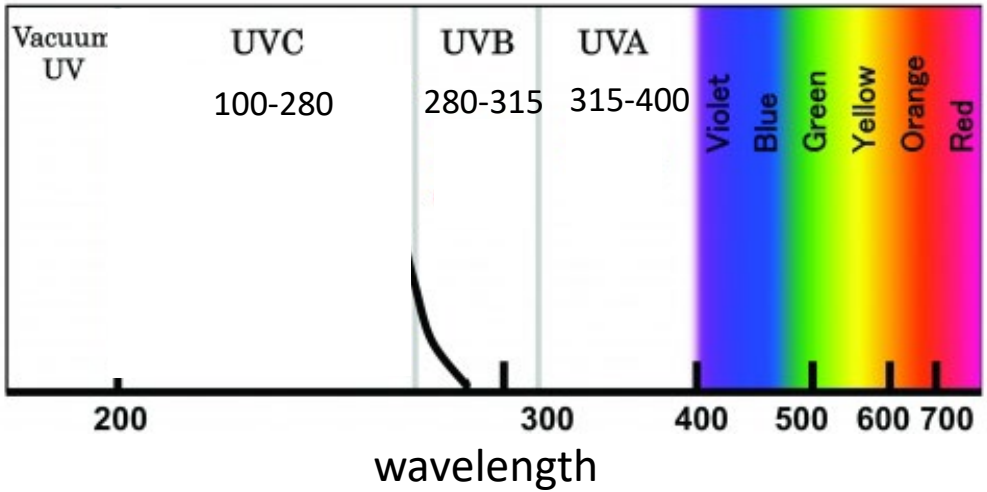
Eumelanin

- Melanin is a polymeric biomaterial that absorbs UV energy striking our skin. It is our natural form of UV protection. Higher amounts of melanin give a darker skin tone
- Extra melanin is produced in response to UV radiation

What happens to the energy from the UV radiation?

It gets converted to heat

Light Matter Interactions - UV



Shorter wavelength = higher energy (e.g. energy of UVB > UVA)

Generally higher energy -> greater damage

https://www.compoundsemiconductor.net/article/91348-building-brighter-and-cheaper-uv-leds.html

Light Matter Interactions - UV

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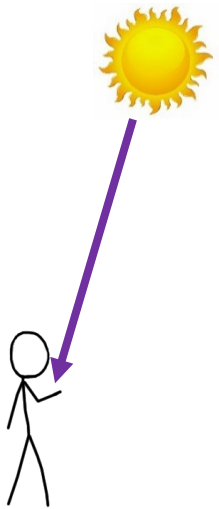

interaction with oxygen

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vitamin D production

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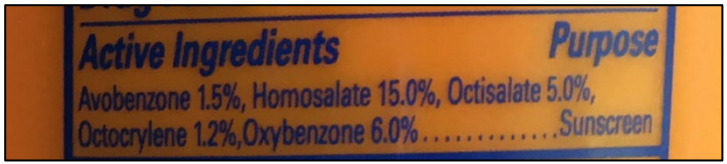
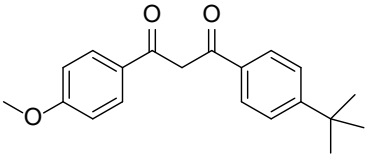
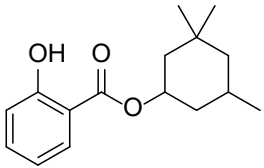
Sunscreen

What's in it?

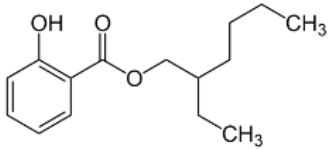




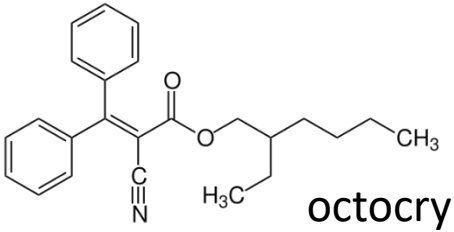
avobenzone



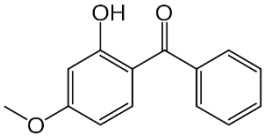
homosalate



octisalate



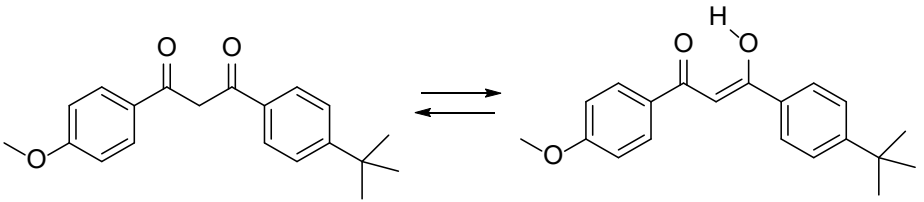
octocrylene



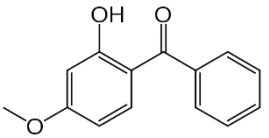
oxybenzone

Sunscreen

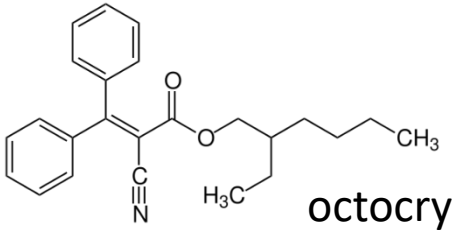
What's in it?



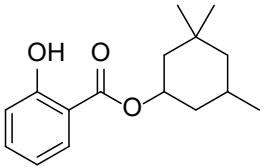
Avobenzone (310-400 nm)



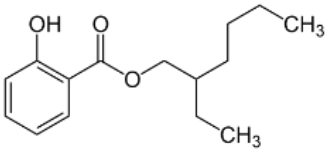
oxybenzone
(290-360 nm)



octocrylene
(290-350 nm)



homosalate
(295-315 nm)



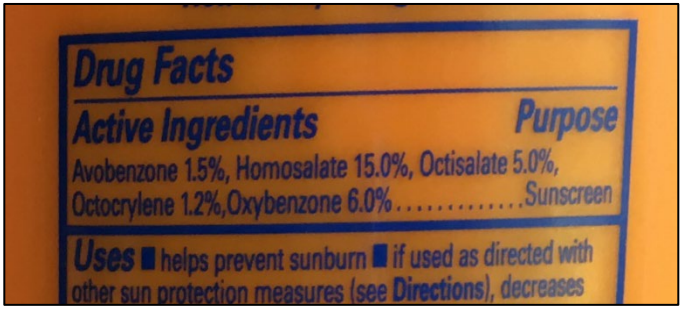
octisalate
(295-315 nm)

What are some common features?

Why does avobenzone absorb better in the UVA?

http://www.smartskincare.com/skinprotection/sunblocks/sunblock_benzophenones-3-and-4.html

Sunscreen



~2012

Some controversy associated with oxybenzone

octocrylene needed as photo-stabilizer for avobenzone

more recent

Sunscreen

What's in it?

Drug Facts

Active Ingredients	Purpose
Titanium Dioxide 3.1%, Zinc Oxide 4.0%	Sunscreen

Uses ■ helps prevent sunburn ■ if used as directed with other sun protection

TiO_2 (290-350 nm)

ZnO (290-400 nm)

Broadest range of any single sunscreen ingredient

Sometimes called "physical" blockers (vs "chemical")

- These work by absorbing/reflecting/scattering UV light

http://www.smartskincare.com/skinprotection/sunblocks/sunblock_benzophenones-3-and-4.html

Solar Energy