

## Atmosphere and Temperature

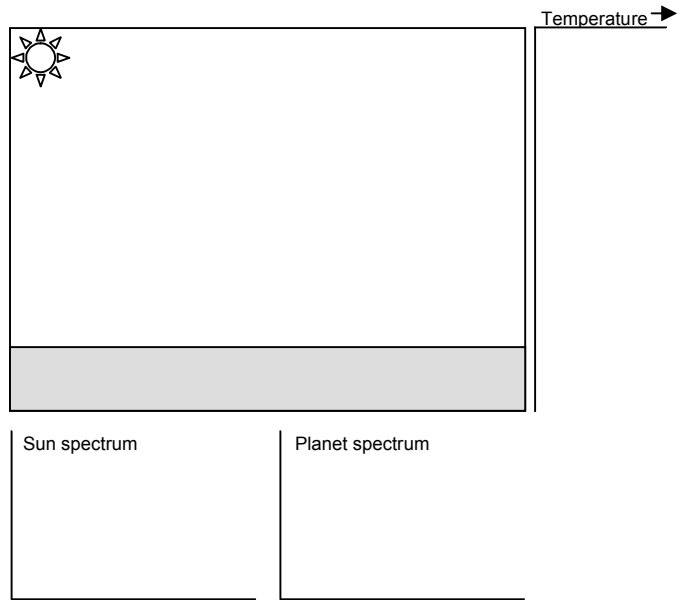
### No Atmosphere

The simplest condition is that where there is no atmosphere.

Solar energy comes in from above in the form of X-rays, UV, visible, and IR light.

All of this energy reaches the surface.

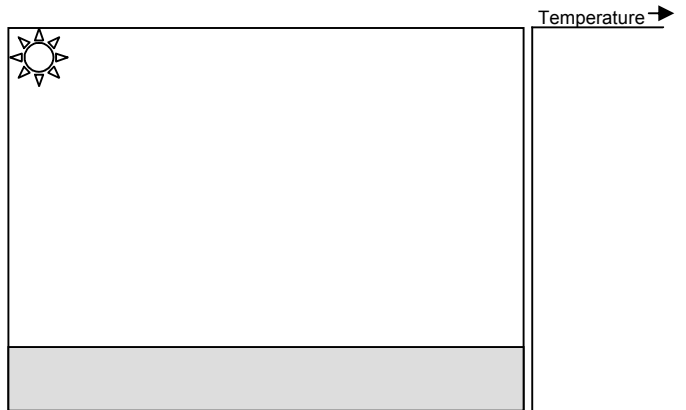
Some of it is reflected back into space. The rest is absorbed by the surface, heating it up. The surface then emits its thermal radiation back into space at infrared wavelengths.



### Inert atmosphere

An inert atmosphere does not react with the light from the Sun or the planet in any way and does not radiate its energy into space – it just transports heat. Such an atmosphere can only gain energy from, and lose energy to, the ground – so it will simply attain the temperature at the planet's surface everywhere.

In addition to transporting heat vertically, an atmosphere can also transport it horizontally, keeping the poles and the night side of the planet warmer by moving heat there from the equator and the day side.

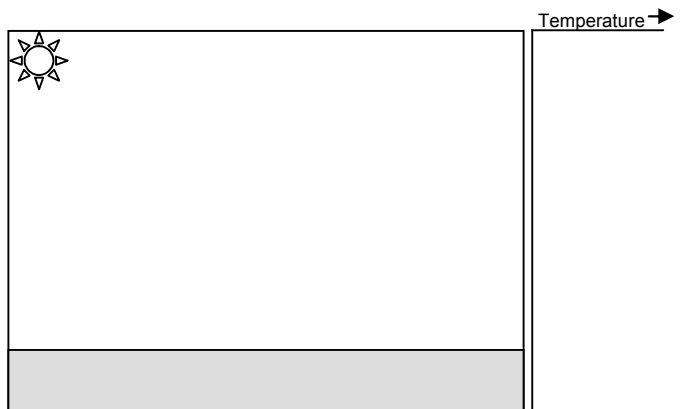


### Nitrogen atmosphere

Nitrogen can *scatter* light – change a photon's direction without actually gaining any energy in the process. However, they preferentially scatter blue light.

The effect of this is that blue light from the Sun is redirected before hitting the surface. The Sun therefore looks slightly yellowish, and the atmosphere itself appears blue. However, the blue light still reaches the surface.

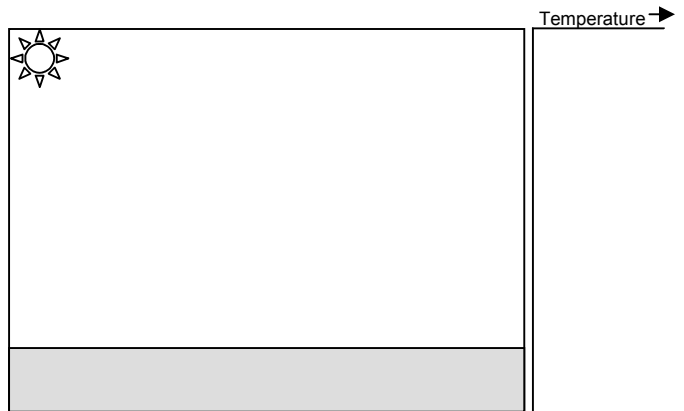
Nitrogen (or any other gas) will also absorb X-rays very high in the atmosphere, making the upper atmosphere very hot.



### Oxygen atmosphere: ozone layer

Ozone ( $O_3$ ) forms in an atmosphere which contains molecular oxygen ( $O_2$ ), but only very high up – not near the surface. Ozone absorbs the ultraviolet radiation, heating up the upper atmosphere. The rest of the solar energy reaches the surface.

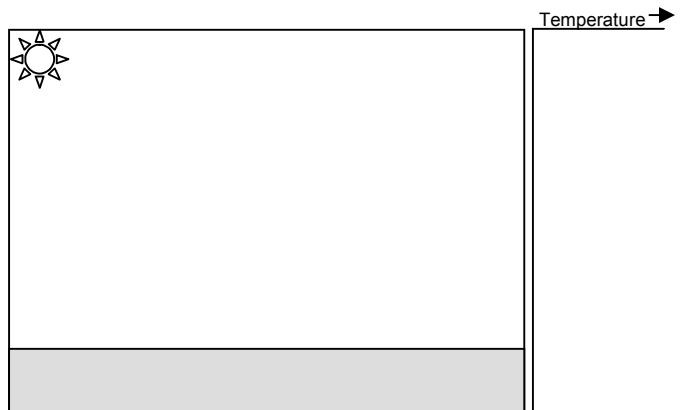
Oxygen also scatters blue light and absorbs X-rays, like nitrogen does.



### Carbon dioxide atmosphere: greenhouse effect

Carbon dioxide has many many absorption lines in the infrared, and so *absorbs* infrared photons very easily. This process heats up the atmosphere.

$CO_2$  does absorb some light from the Sun, preventing it from reaching the surface. Alone this would make the surface cooler (and the upper atmosphere warmer). However, the Sun emits only a fraction of its energy in the IR, whereas the planet's surface emits *all* of this energy in the IR. None of the planet's energy can escape into space, so it builds up in the lower atmosphere until the temperature there is *extremely* hot. (The IR radiation does leak out eventually – the planet cannot heat up to infinity – but it must be emitted and reabsorbed many many times in the lower atmosphere.)



### Combined atmosphere

Earth's atmosphere has all of the above constituents – nitrogen, carbon dioxide, and oxygen (ozone). Sketch the actual temperature structure of Earth at right, and explain with a schematic. Label the different zones of the atmosphere.

