Sequence 11: electromagnetic waves

Fiche de synthèse mobilisée (collection en français) :

- **Fiche n°11a**: lumière et ondes électromagnétiques
- **Fiche n°11b**: spectres de rayonnement
- **Fiche n°11c**: modèle corpusculaire de la lumière

Sommaire des activités ETLV :

ACTIVITY 1: Water and carbon dioxide spectra

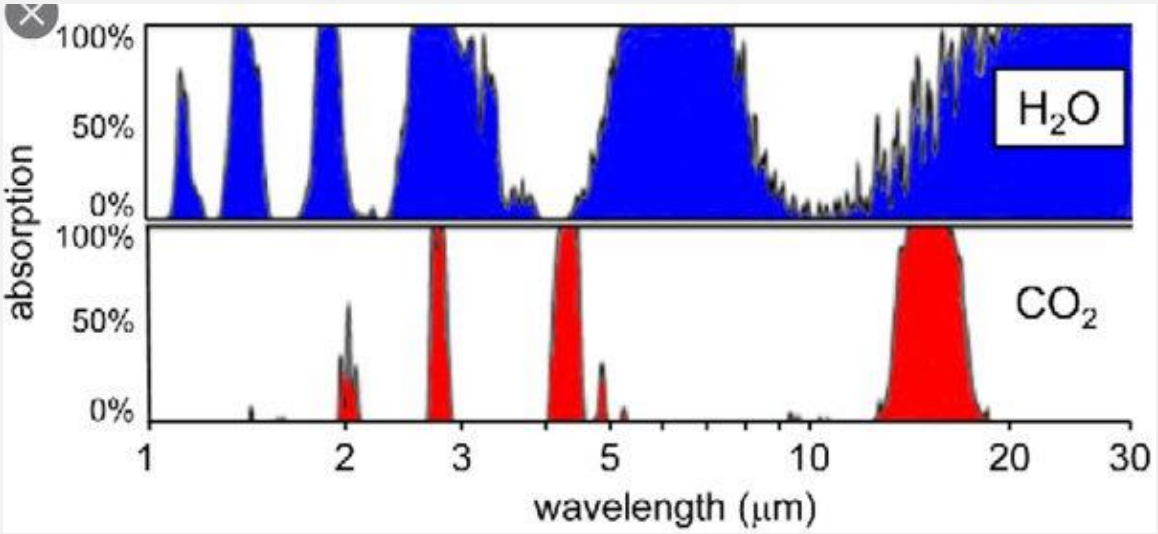
Objective: understanding an absorption spectrum

DOCUMENT 1: carbon dioxide absorption and emission

CO_2 absorbs and emits infrared radiation at main wavelengths of 4.26 µm (2347 cm^{-1}) (asymmetric stretching vibrational mode) and 14.99 µm (667 cm^{-1})

Source: wikipedia

DOCUMENT 2: Water and carbon dioxide spectra



Source: wikipedia

■ **Understanding:**

In document 2, can we see ray spectra or continuous spectra? Explain.

_____

Are documents 1 and 2 in accordance with each other?

_____

ACTIVITY 2: James Webb NASA telescope detects CO_2 on an exoplanet

Objective: understanding how an absorption spectrum can help identify the presence of a chemical species

DOCUMENT 1: NASA's Webb Detects Carbon Dioxide in Exoplanet Atmosphere

NASA's James Webb Space Telescope has captured the first clear evidence for carbon dioxide in the atmosphere of a planet outside the solar system. This observation of a gas giant planet orbiting a Sun-like star 700 light-years away provides important insights into the composition and formation of the planet. The finding, accepted for publication in Nature, offers evidence that in the future Webb may be able to detect and measure carbon dioxide in the thinner atmospheres of smaller rocky planets.

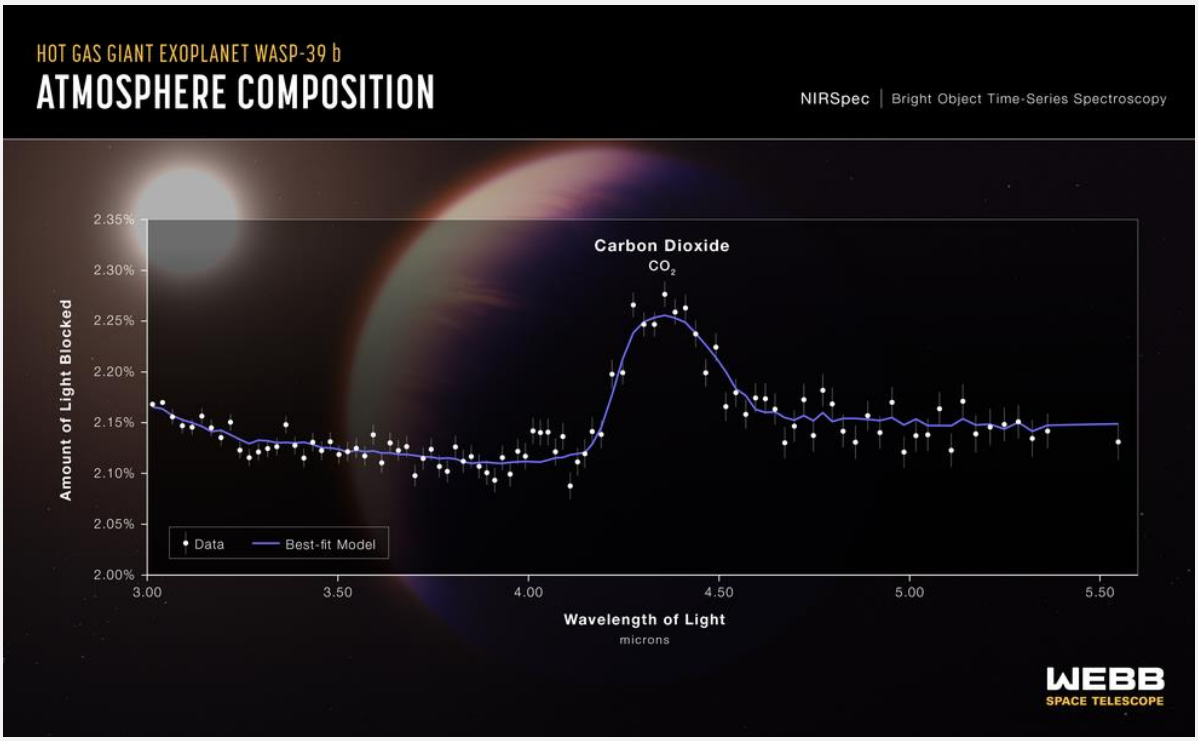
WASP-39b is a hot gas giant with a mass roughly one-quarter that of Jupiter (about the same as Saturn) and a diameter 1.3 times greater than Jupiter.

Previous observations from other telescopes, including NASA's Hubble and Spitzer space telescopes, revealed the presence of water vapor, sodium, and potassium in the planet's atmosphere. Webb's unmatched infrared sensitivity has now confirmed the presence of carbon dioxide on this planet as well.

Source: NASA.gov

DOCUMENT 2: NASA's Webb Detects Carbon Dioxide in Exoplanet Atmosphere

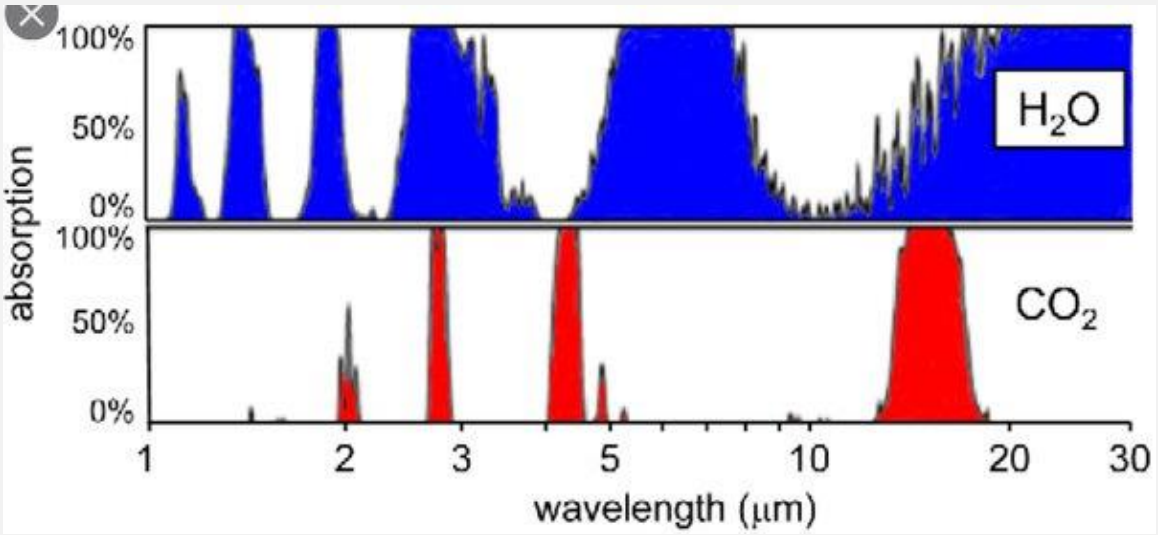
The research team used Webb's Near-Infrared Spectrograph (NIRSpec) for its observations of WASP-39b. In the resulting spectrum of the exoplanet's atmosphere, a small hill between 4.1 and 4.6 microns presents the first clear, detailed evidence for carbon dioxide ever detected in a planet outside the solar system.



Source: NASA.gov on August 25th, 2022

DOCUMENT 3: Water and carbon dioxide spectra

CO_2 absorbs and emits infrared radiation at wavelengths of 4.26 µm (2347 cm^{-1}) (asymmetric stretching vibrational mode) and 14.99 µm (667 cm^{-1})



Source: wikipedia

Acquiring vocabulary:

Read the documents. Find a translation for the following expressions:

English	French
evidence	
a spectrum/spectra	
a hill	
a hot gas giant	
… absorbs and emits	

Understanding:

What is an exoplanet?

_____

Is WASP-39b lighter or heavier than Jupiter? Is it larger or smaller than Jupiter?

_____

Which chemical species had previous telescopes identified on WASP-39b.

_____

Reasoning:

Using documents 2 and 3 explain how the discovery helps to identify carbon dioxide on WASP-39b.

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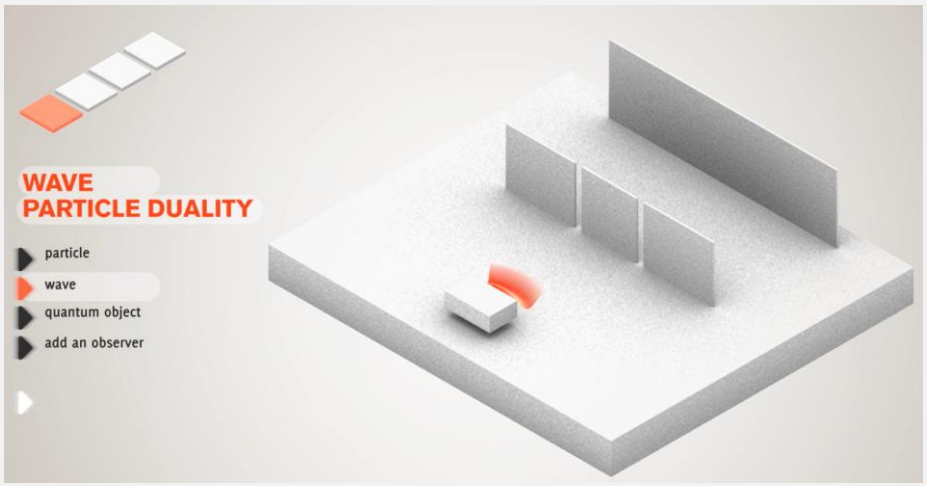
ACTIVITY 3: Wave particle duality

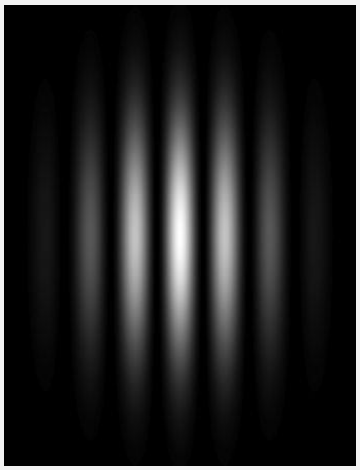
DOCUMENT 1: Wave particle duality animation

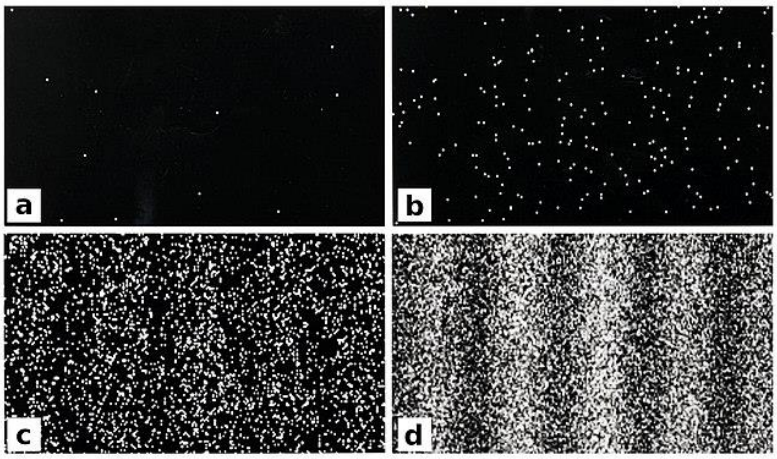


Sources : https://toutestquantique.fr ; Download video without subtitles on the website.

DOCUMENT 2: Double slit experiment results

Since XVIIth century, many scientists proposed a wave theory of light based on experimental observations. One of the most important experiments is the double slit experiment performed for the first time by Thomas Young in 1802.





Left: Simulation by computer of the interference figure from a double slit, same figure obtained by Thomas Young in 1802.

Right: Results of a double-slit-experiment performed by Dr. Tonomura in 2012. Showing the build-up of an interference pattern of single photon or electron. Numbers of particles are 11 (a), 200 (b), 6000 (c), 140000 (d).

Source: wikipedia

According to the wave particle duality animation, answer the following questions:

1. What do you observe on the screen when particles are sent through the double slit?
2. What do you observe on the screen when waves are sent through the double slit?
3. What do you observe on the screen when a quantum object is sent through the double slit?
4. What do you observe on the screen when an observer is added?
5. According to results of the double slit experiment, what can you conclude about the nature of light?

ACTIVITY 4: Types and applications of electromagnetic radiation

DOCUMENT 1: Frequency and energy of an electromagnetic radiation

Through research carried out over many years, light can be considered as particles with no mass, called photons. This particle has a quantified energy $\boldsymbol{E}$ proportional to its frequency $\boldsymbol{f}$:

$$\boldsymbol{E = h \times f = h \times \frac{c}{\lambda}}$$

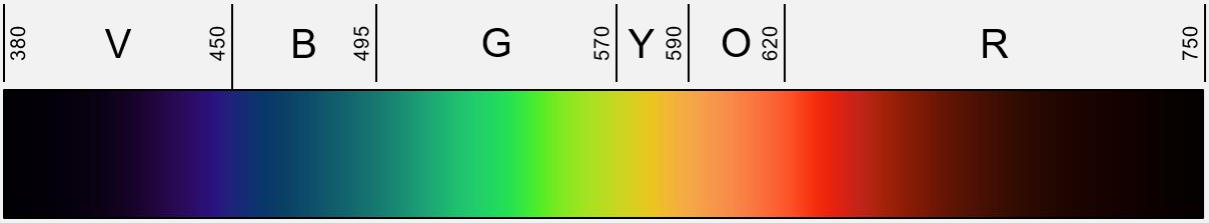
$\boldsymbol{E}$ energy in J; for a photon the energy is usually given in eV: 1eV = $1{,}6.10^{-19}$ J;

$\boldsymbol{h}$ Planck's contant : $6.62.10^{-34}$ J.s;

$\boldsymbol{f}$ frequency in Hz can be written as the ratio of $\boldsymbol{c}$ the speed of light $3{,}0.10^{8}$ m.s^{-1} by $\boldsymbol{\lambda}$ the wavelength in m ;

DOCUMENT 2: Visible light

Visible light is a range electromagnetic radiation that can be detected by the human eyes. This type of radiation is produced by a high temperature object or a semi-conductor. Visible light is composed of every radiation which include a wavelength between 400 nm and 800 nm.



Source: wikipedia

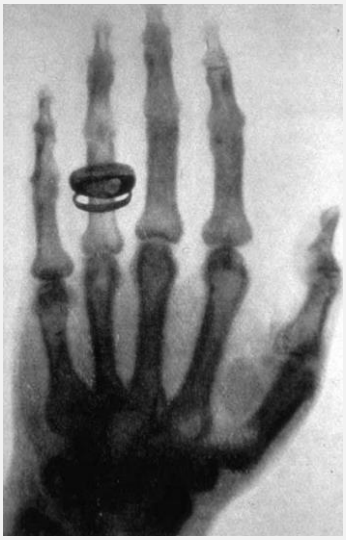
DOCUMENT 3: Radio waves

Radio waves have the longest wavelengths, around 10 m. Radio waves can be generated by charged particles in undergoing acceleration in astronomical objects. Radio waves can be produced artificially by an electronic device called a transmitter and can be used to send a signal over long distances.

Source: wikipedia

DOCUMENT 4: X-rays

X-rays are a part of the electromagnetic radiation that have penetrating properties according to short wavelength around 100 pm. X-ray are naturally emitted by big astronomical objects. It can be generated by applying a high voltage between two electrodes in a discharge tube, electrons are projected in straight line between electrodes. The braking of electrons when they reach the electrode, it produces a high energy radiation. Their discovery in 1895 by Wilhelm Röntgen was awarded by a Nobel prize.



Source: wikipedia

DOCUMENT 5: Infra-red

Infra-red are electromagnetic waves of the radiation that have wavelengths longer than the visible, around 1 mm. This type of radiation is produced by every object even at low temperature. This type of radiation is composed of half of the sun's total electromagnetic radiation.

Source: wikipedia

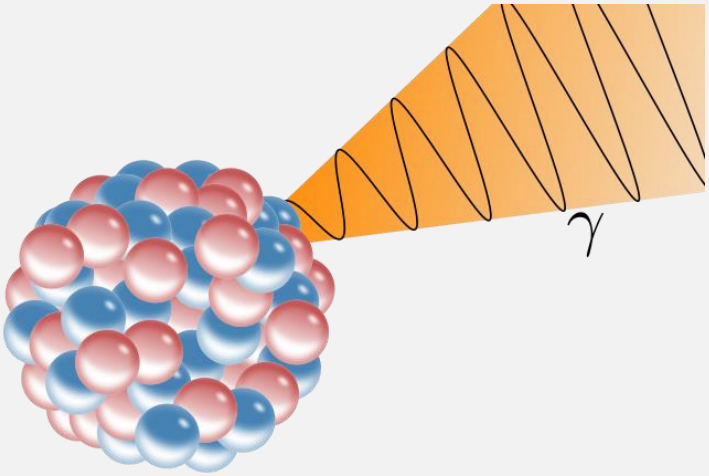
DOCUMENT 6: Microwaves

Microwaves are a part of the electromagnetic radiation that have wavelengths shorter than the radio waves and a frequency around 10^{10} Hz. This type of radiation is emitted by astronomical objects and generated artificially by an antenna. Microwaves are useful for point to point communications as mobile phone and network. Some frequencies can be also absorbed by the water to heat it.

Source: wikipedia

DOCUMENT 7: Gamma rays

Gamma rays are a part of the electromagnetic radiation that have high penetrating properties according to its frequency around 10^{19} Hz. Naturally this type of radiation comes from radioactive decay of nuclei or from atmospheric interactions with cosmic ray particles. Gamma rays can cause damages on living cells but are also use in medicine as imaging agent to identify tumoral cells.



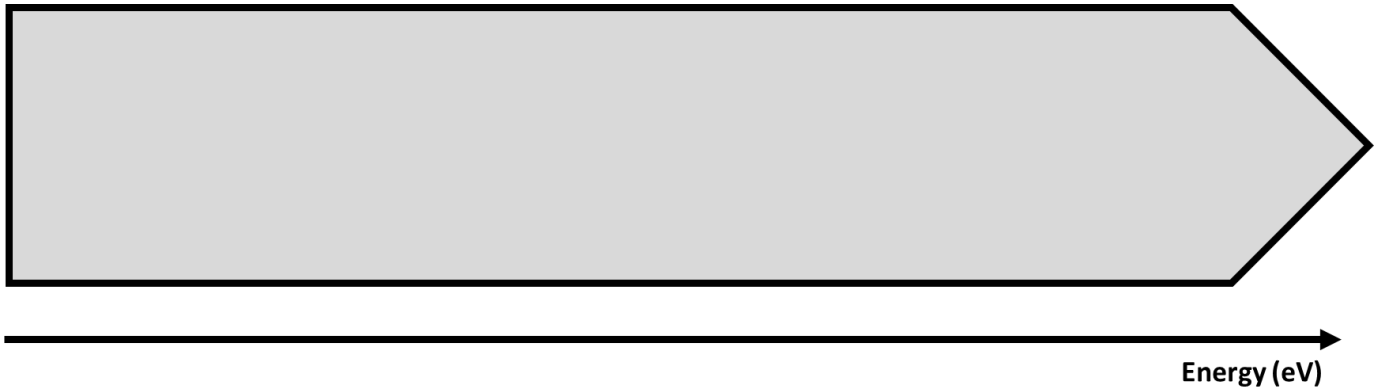
Source: wikipedia

DOCUMENT 8: Ultra-violet

Ultra-violet are a part of the electromagnetic radiation that have wavelength shorter than the visible and frequency around 10^{16} Hz. This type of radiation is produced by high temperature surfaces such as the sun and constitute about 10% of its total electromagnetic radiation. UV radiation interacts with organic molecules and biologic system and causes some substances to glow and has many practical applications.

Source: wikipedia

1. Classify the types of electromagnetic radiation by increasing energy of a photon.



2. Give an application for each type of electromagnetic radiation.

Activity summary

What you must remember:

- **Nature of an electromagnetic radiation**
- **Energy and frequency of an electromagnetic radiation**
- **Specific vocabulary:**

English	French
wavelength	longueur d'onde
slit	fente
screen	écran
heat	chaleur
ray	rayonnement

English	French
network	réseau
nucleus	noyau
decay	désintégration
glow	briller

Skills linked to the curriculum:

Compétences	Capacités à maîtriser	Où dans cette séquence ?
APP	• Utiliser du vocabulaire spécifique	Activités 1 à 4
	• Lire et comprendre des documents scientifiques	Activités 1 à 4
COM	• S'exprimer à l'écrit et à l'oral en utilisant le vocabulaire adapté	Activités 1 à 4
REA	• Distinguer spectres continus et spectres de raies. • Interpréter et exploiter la présence de raies dans un spectre à l'aide de données tabulées • Application d'une formule • Conversions	Activité 1 Activité 2 Activité 3
VAL	• Valider une hypothèse à partir de données tabulées	Activité 2