Greenhouse gases

4.9.2.1 · Chemistry of the atmosphere · revision notes

Why the Earth is warm enough for life: greenhouse gases absorb long wavelength radiation given out by the Earth's surface. Expect 'name' questions and 2 to 4 mark 'describe' or 'explain' questions on the greenhouse effect in terms of short and long wavelength radiation.

Key facts

- Greenhouse gases: water vapour, carbon dioxide, methane
- Sun → short wavelength radiation → passes through the atmosphere → absorbed by the Earth's surface
- Greenhouse gases absorb long wavelength radiation and re-emit it in all directions
- Nitrogen and oxygen are not greenhouse gases
- They keep the Earth warm enough to support life
- Warm Earth's surface → gives out long wavelength (infrared) radiation
- More greenhouse gases → more radiation absorbed → higher average temperature

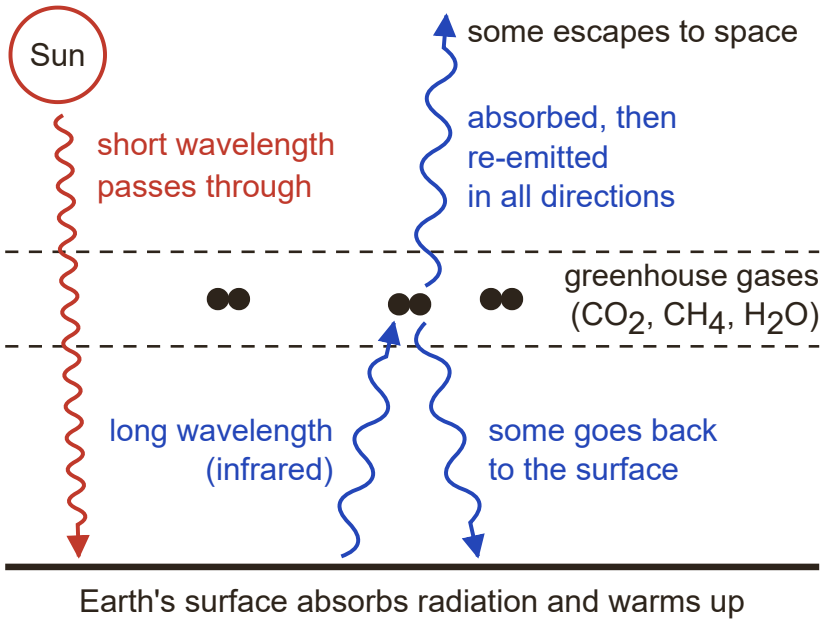
Notes

What greenhouse gases do

- **Greenhouse gases** in the atmosphere keep the Earth's temperature **high enough to support life**. Without them the Earth would be far too cold.
- The greenhouse gases you need to know are **water vapour** (H_2O), **carbon dioxide** (CO_2) and **methane** (CH_4).
- Nitrogen and oxygen, the main gases in air, are **not** greenhouse gases.
- The greenhouse effect is natural and needed. The concern is that human activities are adding more greenhouse gases and making it stronger.

The greenhouse effect step by step

- 1. The Sun gives out mainly **short wavelength** radiation (for example visible light).
- 2. Most of this short wavelength radiation passes through the atmosphere. Much of it is **absorbed by the Earth's surface**, which warms up.
- 3. The warm Earth's surface gives out **long wavelength** radiation (**infrared**).
- 4. Greenhouse gas molecules **absorb** some of this long wavelength radiation.
- 5. They then **re-emit** it in **all directions**, including back towards the Earth's surface. This keeps the surface and the lower atmosphere warmer.



Greenhouse gases let short wavelengths in but absorb and re-emit some of the long wavelengths going out.

More greenhouse gas, more warming Grade 7+ only

- Greenhouse gases let most of the incoming short wavelength radiation through, but absorb some of the outgoing long wavelength radiation. The difference in wavelength is the key idea.
- If the amount of greenhouse gases increases, more long wavelength radiation is absorbed and re-emitted back towards the Earth, so less escapes into space.
- Energy still arrives from the Sun at the same rate but escapes more slowly, so the Earth's average temperature rises.

How to answer each type of question

Name or identify greenhouse gases

1 to 2 marks | Grade 3

1. Learn the three: water vapour, carbon dioxide, methane.
2. Tick only the number of boxes the question asks for.

Example. Which **two** of these gases are greenhouse gases?
argon carbon dioxide methane nitrogen oxygen

Model answer.

carbon dioxide (1)
methane (1)

Explain the greenhouse effect in terms of radiation

3 to 4 marks | Grade 5

1. Start with the Sun: short wavelength radiation passes through the atmosphere.
2. The Earth's surface absorbs it, warms up and emits long wavelength (infrared) radiation.
3. Greenhouse gases absorb some of the long wavelength radiation.
4. They re-emit it in all directions, including back towards the Earth.

Example. Explain how greenhouse gases keep the Earth's surface warm.
Refer to the wavelengths of radiation in your answer.

Model answer. Short wavelength radiation from the Sun passes through the atmosphere (1) and is absorbed by the Earth's surface, which warms up (1). The Earth's surface emits long wavelength (infrared) radiation (1). Greenhouse gases absorb some of this long wavelength radiation and re-emit it in all directions, including back towards the Earth (1).

Explain the effect of increasing a greenhouse gas

2 marks | Grade 7

1. Say that more of the long wavelength radiation emitted by the Earth is absorbed.
2. Say that less escapes into space (more is re-emitted towards the Earth), so the average temperature rises.

Example. The concentration of methane in the atmosphere is increasing.
Explain why this could cause the Earth's average temperature to rise.

Model answer. More methane molecules absorb more of the long wavelength radiation emitted by the Earth's surface (1). More radiation is re-emitted back towards the Earth and less escapes into space, so the average temperature rises (1).

Evaluate an experiment or model

2 to 3 marks | **Grade 8**

1. Compare the model with the real atmosphere: amount of gas, how the gas is heated, size and complexity.
2. Comment on the method: repeats, control variables, only one result.
3. Say what the model does show, as well as its limits.

Example. A student placed a thermometer in each of two sealed flasks. One contained air and the other contained air with extra carbon dioxide. Both flasks were placed under the same lamp. The flask with extra carbon dioxide warmed up more.
The student said: 'This proves that more carbon dioxide in the atmosphere will cause global warming.'
Give **two** reasons why the student's conclusion is not fully justified.

Model answer.

Any two from:

it was done only once, so the result may not be repeatable (1)

the flask contains much more carbon dioxide than the atmosphere does (1)

the lamp heats the gas directly, whereas in the atmosphere the gases absorb long wavelength radiation emitted by the Earth's surface (1)

the real atmosphere is much more complex, e.g. clouds, oceans and other gases also affect the temperature (1)

Don’t lose marks

- Saying greenhouse gases 'reflect heat', or only that they 'trap heat'. Say they absorb long wavelength (infrared) radiation and re-emit it.
- Saying the radiation from the Sun is long wavelength. The incoming radiation is mainly short wavelength; the Earth emits long wavelength.
- Mixing up the greenhouse effect with the ozone layer. They are not the same thing, so don't mention the ozone layer.
- Forgetting that water vapour is a greenhouse gas, or naming nitrogen or oxygen as greenhouse gases.
- Saying greenhouse gases are harmful. Without them the Earth would be too cold for life; the problem is increasing amounts of them.

More tips

Memory tricks

- Short in, long out: short wavelength comes in from the Sun, long wavelength goes out from the Earth and is absorbed by greenhouse gases.
- The three gases: 'Warm Climate Makers': Water vapour, Carbon dioxide, Methane.
- Full-marks chain: Sun → short wavelength → surface absorbs → long wavelength emitted → gases absorb → re-emit in all directions.

Exam technique

- If the question says 'in terms of radiation' or 'refer to wavelength', you must use the words short wavelength and long wavelength.
- Write the steps in order: each step is usually one marking point.
- 'Absorb' and 're-emit in all directions' are the key phrases examiners look for.
- You can write 'infrared' as well as 'long wavelength', but not 'heat rays'.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3

Name three greenhouse gases

Water vapour, carbon dioxide and methane are greenhouse gases.

Grade 4

State why greenhouse gases are needed

They keep the Earth's temperature high enough to support life.

Grade 5

Describe what happens to the Sun's radiation

Short wavelength radiation from the Sun passes through the atmosphere and is absorbed by the Earth's surface, warming it.

Grade 5

Describe the greenhouse effect using wavelengths

The warm surface emits long wavelength radiation, which greenhouse gases absorb and re-emit in all directions.

Grade 7

Explain why more greenhouse gases cause warming

More long wavelength radiation is absorbed and re-emitted towards the Earth, so less escapes to space and the average temperature rises.

Grade 8

Evaluate a model of the greenhouse effect

Compare an experiment or model with the real atmosphere and judge what it does and does not show.

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