ENV 320 – Chemical composition

Exercise session

04.04.2025

What are aerosols ?

Aerosols are solid or liquid particles, not gases.

0 ×

Gaseous pollutants emitted by factories and vehicles.

0 ✓

Solid or liquid particles suspended in the air.

Water vapor is a gas, while aerosols are solid or liquid particles.

0 ×

Water vapor forming clouds in the atmosphere.

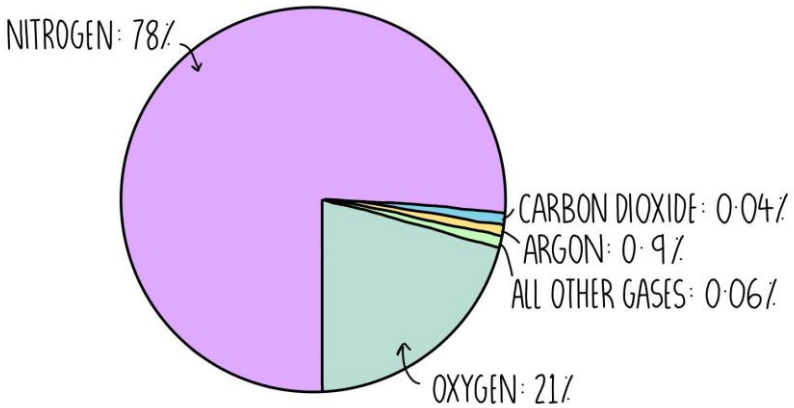
Which of the following compounds are air pollutants ? (multiple answers)

Makes up ~78% of the atmosphere and is not harmful.

From ocean spray.

0 ✓	0 ×	0 ×	0 ✓	0 ✓
Particulate matter (PM)	Nitrogen (N2)	Sea salt particles	Carbon monoxide (CO)	Sulfur dioxide (SO2)

What is a trace gas and which examples are correct ? (multiple answers)



0 ✓

Gases that are present in small amounts in the atmosphere.

0 ×

Gases that are abundant in the atmosphere.

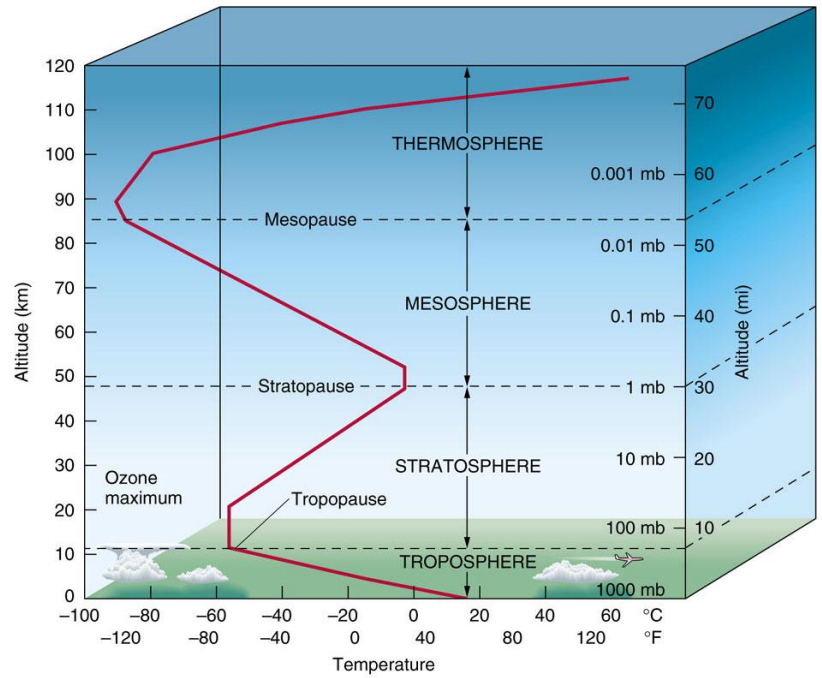
0 ×

Oxygen (O2), Nitrogen (N2), Argon (Ar)

0 ✓

Carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), ozone (O3)

In which atmospheric layer(s) is the temperature decreasing with altitude ?



0 ✓ Troposphere

0 ✗ Stratosphere

0 ✓ Mesosphere

0 ✗ Thermosphere

(1) Are ppmm and ppmv the same ? (2) What does 420 ppm of CO2 actually stand for ?

ppmv = part per million by volume (µL/L, cm³/m³, etc.)
ppmm = part per million by mass (mg/kg, µg/g, etc.)

Exercise : Please convert 420 ppmv of CO_2 into ppmm.

$$ppmv = ppmm \cdot \frac{M_{air}}{M_{CO_2}}$$

M_{air} = 28.97 g/mol (average molar mass of dry air)
M_{CO2} = 44.01 g/mol (molar mass of CO_2)

Solutions :

$$ppmm = ppmv \cdot \frac{M_{CO_2}}{M_{air}} = 420 \cdot \frac{44.01}{28.97} = 638\ ppmm$$

0 ✗	0 ✓	0 ✓	0 ✗
(1) Yes	(1) No	(2) 420 ppmv	(2) 420 ppmm

Why do we use Standard Temperature and Pressure (STP) when expressing number concentrations ?

Gases expand and contract with temperature and pressure changes

0 ×

Gases have a fixed volume regardless of T and P.

0 ✓

Consistency and comparability of measurements by using a ref T and P.

0 ×

Chemical composition of gases changes at different temperatures.

0 ×

Prevent gases from reacting with each other in the atmosphere.

Which of the following options is the correct labelling ?

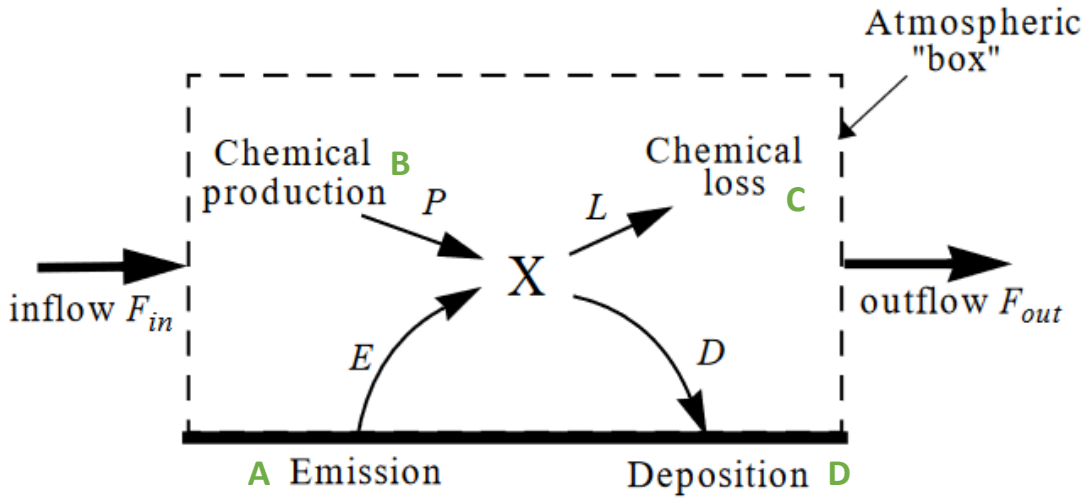


Figure 3-1 One-box model for an atmospheric species X

0 ×

(A) Chem. Production, (B) Emission, (C) Deposition, (D) Chem. Loss

0 ×

(A) Emission, (B) Photochemsitry, (C)Chemical Loss, (D) Oxidation

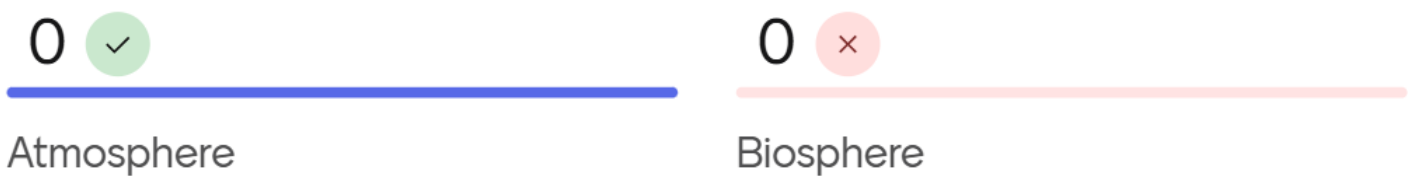
0 ✓

(A) Emission, (B) Chem. Production, (C) Chem. Loss, (D) Deposition

0 ×

(A) Deposition, (B) Long-range transport, (C) Reduction, (D) Gravity

Which one contains more carbon : the atmosphere or the biosphere ?



Global Carbon Cycle

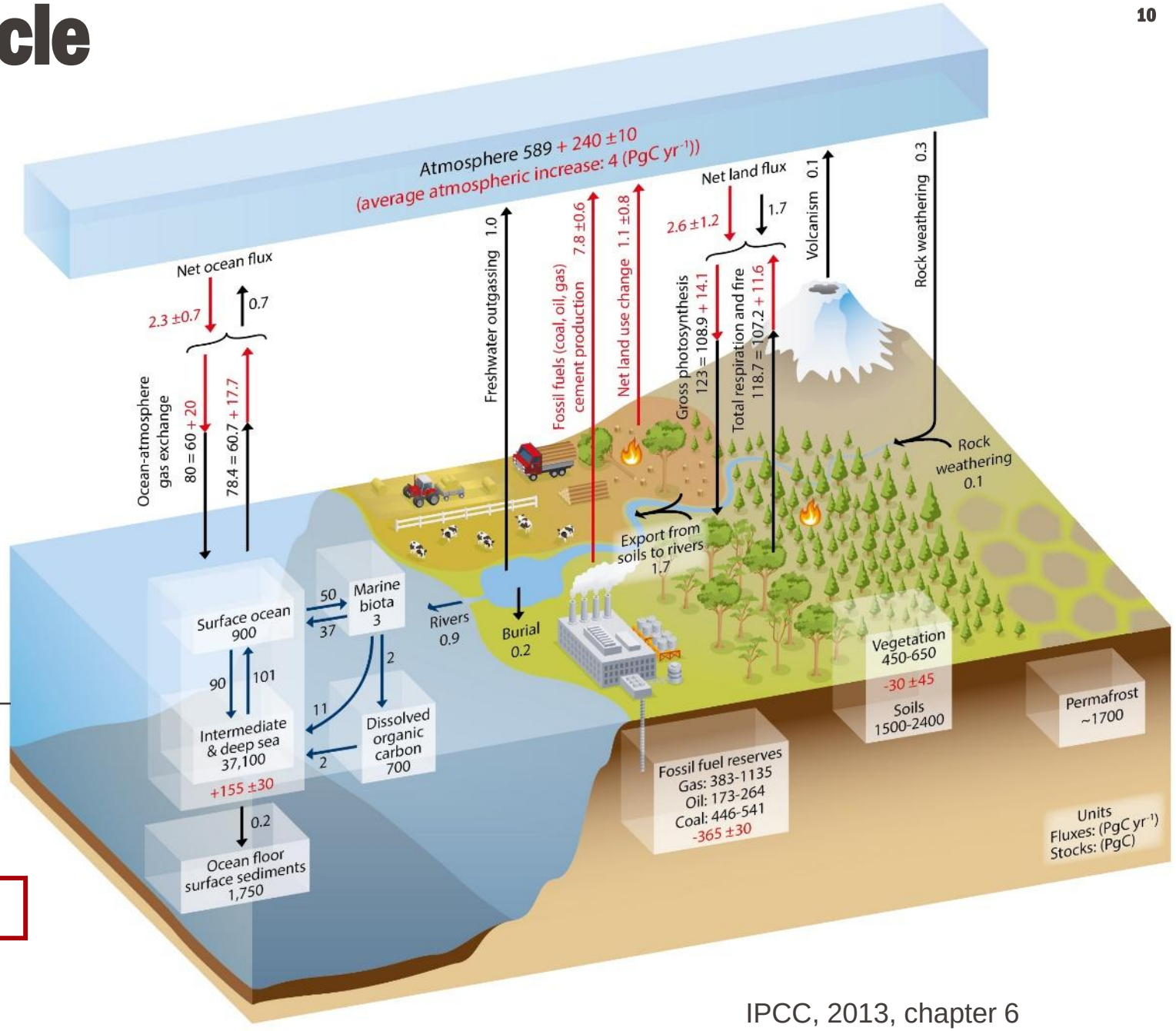
Units: PgC (1 PgC = 10^{15} gC), PgC yr^{-1}

Black: reservoir or fluxes prior to 1750 (pre-industrial), reservoir also called «carbon stock»
Red: «anthropogenic» fluxes 2000-2009

Two domains:
«Fast»: carbon in the atmosphere, the ocean, surface ocean sediments and on land in vegetation, soils and freshwaters
Slow: carbon stores in rocks and sediments

They exchange via volcanic eruptions and chemical weathering of rock.

Location	% C	Type of carbon
Lithosphere	99.985	fossil, sediments, organic carbon, marine sediments
Hydrosphere	0.0076	carbonate ions, dissolved CO2, biocarbonate ions
Pedosphere	0.0031	soil organisms, plant remains
Cryosphere	0.0018	frozen mosses
Atmosphere	0.0015	gaseous carbon
Biosphere	0.0012	living plants and animals



IPCC, 2013, chapter 6

Why is the Haber-Bosch process so important ?

Produces ammonia, not oxygen.

0 ×

It produces oxygen for industrial use.

Ammonia is not primarily used as fuel.

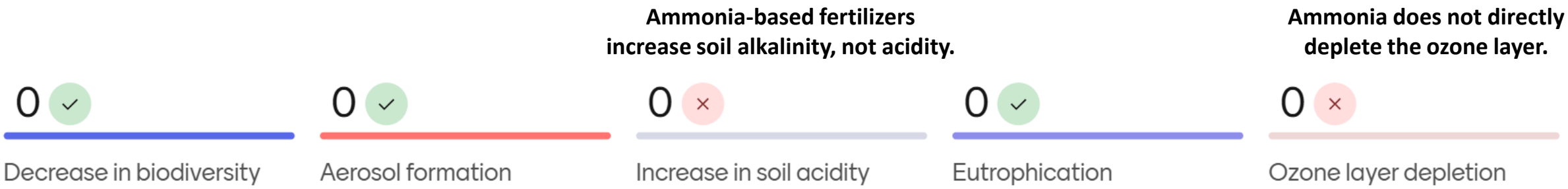
0 ×

It contributes to the synthesis of ammonia, which is mainly used as a fuel for transportation.

0 ✓

It allows for the large-scale production of ammonia, which is essential for fertilizers and boosts agricultural yields.

Ammonia is a great fertilizer, but it can also lead to ... (multiple answers)



Which molecule has a longer atmospheric lifetime ?

Table 1
Atmospheric lifetimes GWP_{100} of greenhouse gases [8]

Greenhouse gases	Atmospheric lifetime (year)	GWP_{100}
CO_2	50-200	1
CF_4	50000	6500
C_2F_6	10000	9200
SF_6	3200	23900
C_3F_8	2600-7000	7000
CHF_3	250-390	11700
C_4F_8	3200	8700
CH_4	12	21
N_2O	120	310
NF_3	50-740	8000

SH Han et al. 2009

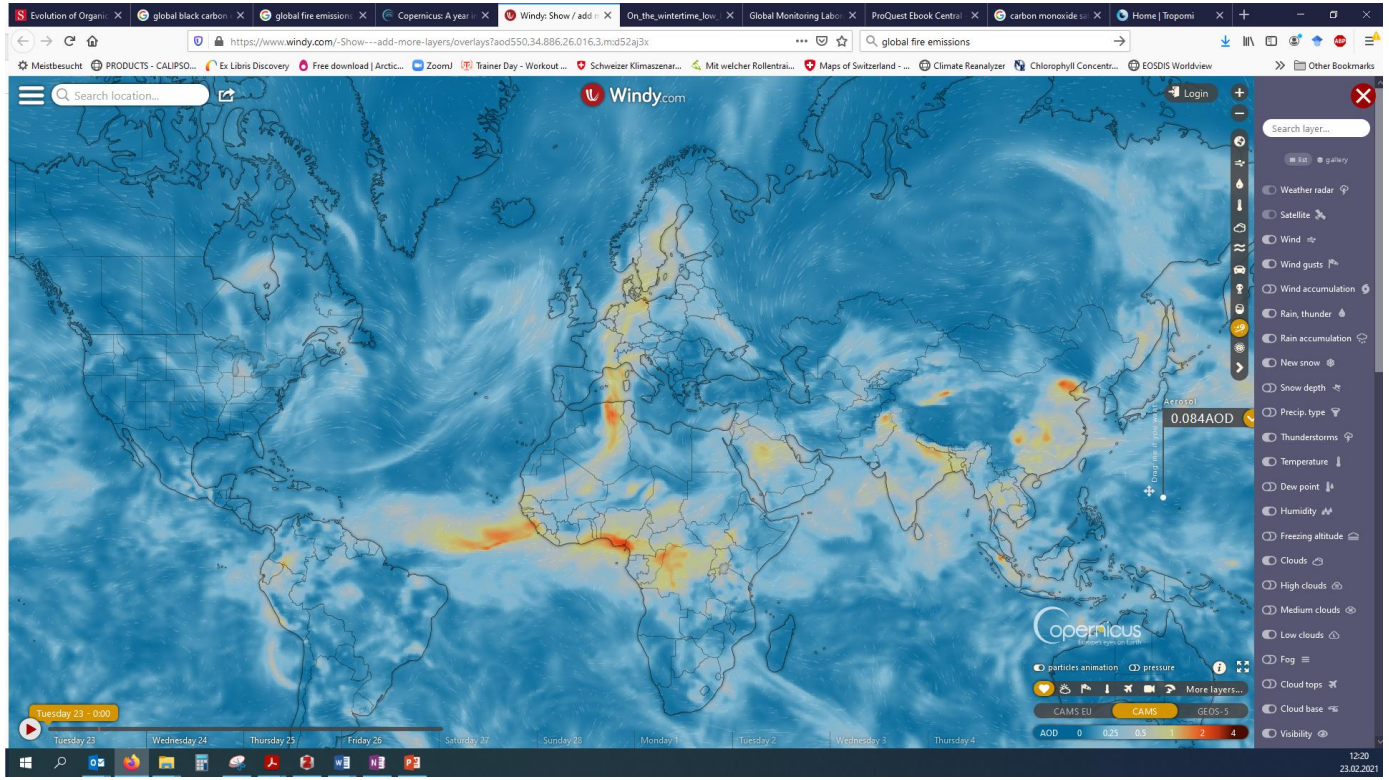
0 ✓

Carbon dioxide (CO2)

0 ×

Methane (CH4)

Why is the lifetime of atmospheric pollutants important when considering their global transport ?



Saharan dust transport : good visual representation of how long-lived air pollutants are spreading through global transport.

0 ✓

Longer-lived pollutants travel farther and impact distant regions.

0 ×

All pollutants mix evenly, so lifetime doesn't affect transport.

0 ×

Short-lived pollutants reach the stratosphere.

0 ×

Longer-lived pollutants always have stronger local effects.

Is the atmospheric lifetime of SO2 longer in the stratosphere or in the troposphere ? Why is it longer in one of them? (select 2 answers)

OH is the «washing agent» of the troposphere.

0 ✓	0 ×	0 ×	0 ✓
Stratosphere	Troposphere	Reason : stratosphere is higher	Reason : OH is "washing" the troposphere

Common air quality units

Calculation not done during lecture

- Particulate matter (PM)
  - ≤ 10 µm: PM_{10}
  - ≤ 2.5 µm: $PM_{2.5}$
- Swiss standard
  - $PM_{2.5}$: 10 µg m^{-3} (annual mean), 25 µg m^{-3} (daily mean)
  - PM_{10} : 20 µg m^{-3} (annual mean), 50 µg m^{-3} (daily mean)

- Ozone

CH:

- < 100 µg m^{-3} (98 % of ½ -h averages in one month)
- 120 µg m^{-3} hourly average, only to be surpassed once per year

USA

- 0.070 ppm (8-hour average)

Who is stricter?

Calculation not done during lecture

CH

120 µg m^{-3} hourly average

USA

0.070 ppm (8-hour average)

What you need to know

Loschmidt's number:

Number of molecules per m^3 at STP

2.687×10^{25}

$$\frac{volume\ occupied\ by\ O_3}{volume\ occupied\ by\ air} = \frac{number\ of\ O_3\ molecules\ per\ m^3}{total\ number\ of\ molecules\ per\ m^3}$$

Molecules per mol: $6.022 * 10^{23}$
Molecular weight of O_3: 48 g / mol

Solution

Calculation not done during lecture

Loschmidt's number:

Number of molecules per m^3 at STP

2.687×10^{25}

$$\frac{volume\ occupied\ by\ O_3}{volume\ occupied\ by\ air} =$$

$$\frac{number\ of\ O_3\ molecules\ per\ m^3}{total\ number\ of\ molecules\ per\ m^3}$$

USA (8-hour average)

$0.070\ ppm = 0.07\ * 10^{-6}$

$number\ of\ O_3\ molecules\ m^{-3} =$

$0.07\ * 10^{-6} * 2.687 * 10^{25} = \mathbf{1.88 * 10^{18}}$ molecules/m^3

Molecules per mol: $6.022*10^{23}$

Molecular weight of O_3: 48 g / mol

$number\ of\ moles\ of O_3\ m^{-3} =$

$$\frac{1.88 * 10^{18}}{6.022*10^{23}} = 3.12\ * 10^{-6}\ \text{mol/m}^3$$

$\mu g\ of O_3\ m^{-3} = 3.12\ * 10^{-6} * 48 * 10^6 = \mathbf{149.92}$ µg/m^3

Switzerland: 120 µg m^{-3} (hourly)

→ Switzerland is stricter