CH3041 Tutorial 1 Answers

1. Nitrogen is a major gas in the troposphere. Calculate the partial pressure (torr) of nitrogen 3.00 km above sea level given that nitrogen comprises 78.084% by volume of the permanent gases in the troposphere. You will need to use the barometric law and assume ideal gas behaviour and standard temperature (0.00^{o}C). Atmospheric pressure at sea level is 760 torr and the scale height is 8.40 km.

Assuming ideal gas behaviour 1 mol of any gas occupies 22.4 dm^3
Therefore the volume % is the same as a mol %.

$p_i = (\%_i / 100)\ p_{atm}$ $\qquad$ $p_z = p_o \exp(-z / H)$ where H = 8.40 km

$p_{atm} = p_o \exp(-3 / 8.4) = 760 \times 0.6997 = 531$ torr

$p_{N2} = \%_{N2}\ p_{atm} = 0.78084 \times 531 = 415.2$ torr = **415 torr**

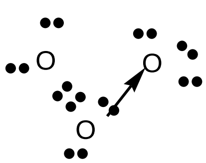
2. Describe the **Chapman mechanism** for the formation of **ozone** in the stratosphere.
   - Draw Lewis dot and VSEPR structures for ozone.
   - Why is the presence of ozone in the stratosphere regarded as essential for the success of most life-forms on the planet and yet it is harmful to may of those some life-forms in the lower troposphere?

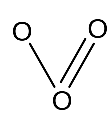
The Chapman Mechanism for the formation of ozone:

The formation of O_3, produces 350 kT / d

	UV-C $h\nu$, $\lambda < 240$ nm	ΔH, kJ/mol
1)	$O_2 \rightarrow 2O$	$495 - E_{h\nu}$
	3rd Body M (absorbs excess E)	
2)	$O + O_2 \rightarrow O_3$	-105

This reaction occurs in a region of the stratosphere (15 -35 km) which is called the ozone layer.
The concentration of ozone is not high (9 - 11ppm) in this layer and so ozone is still a trace gas but the absorption of radiation both in the formation and destruction of ozone is vital as it acts as a radiation shield for life on the planet. The net energy change associated with the reaction is exothermic and so there is a heating effect in this region of the atmosphere.





electronic strucure 3 regions at the central O
molecular structure bent

Ozone in the stratosphere is a radiation shield which prevents UV-B and UV-C photons from impacting on the Earths surface. UV-C in particular is harmful to DNA and causes damage which results in mutagenic and carcinogenic effects.
Ozone in the troposphere acts as a poison as it is a very powerful oxidant and destroys cellular organisms (used for disinfecting water) as well as irritating the lungs and eyes of humans.

3. In pollution monitoring aerosol particles are routinely monitored as well as toxic gases.
   - Provide **three examples** of common **aerosols** and describe how these particles originate.
   - Why are aerosol particles often regarded as a health problem?

Aerosol particles are small : < 10^{-5} m to remain in the atmosphere for extended periods of time.
Sea-salt aerosol : formed by evaporation of the droplets ejected from the surface of the ocean in breaking waves. Evolve into Na_2SO_4 aerosol
Dust aerosol : formed from the physical abrasion of continental rock, the particle dimension (< 10^{-5}m) means that the particles stay suspended.
Organic (low volatility acids, polynuclear aromatics or derivatives)
NH_4NO_3, non sea salt SO_4 aerosol Na_2SO_4, carbon black

Aerosol particles < 2.5 μm are of such a size that they can enter the blood stream directly in the lungs. As many of these particles involve heavy toxic metals (such as Hg or Pb) and carcinogenic organic compounds such as PAH it is of great concern that these can directly enter the blood stream where they will act in a systemic poison.

4. In a pollution monitoring exercise a 1.00 m^3 sample of air was found to contain 80 μg/m^3 of SO_2. The temperature and pressure were 25.0°C and 103.193 kPa when the air sample was taken.
   - What was the SO_2 concentration in ppm? Assume ideal gas behaviour for the gas 1mol = 22.414 dm^3 at 273K and 101.325 Pa.

MW (SO_2) = 32.06 + 2(15.9994) = 64.06 g/mol

T(K) = 25.0°C + 273K = 298 K

We may write an equation that converts the mass of the sulphur dioxide g_{SO2} in grams to its equivalent volume V_{CO} in litres:

$$
\begin{aligned}
V_{SO2} &= \underline{g_{SO2\,/}}\, M_{SO2} \times 22.414 \text{ L/mol} \\
&= 80 \times 10^{-6} \text{ g} / 64.06 \text{ g/mol} \times 22.414 \text{ L / mol} \\
&= 1.2488 \times 10^{-6} \text{ mol} \times 22.414 \text{ L / mol} \\
&= 2.791 \times 10^{-5} \text{ L}
\end{aligned}
$$

The volume now needs to be corrected to STP

$$V_{SO2\text{ -corr}} = V_{SO2} \times \frac{298\text{K}}{273\text{K}} \times \frac{101.325 \text{ kPa}}{103.19 \text{ kPa}}$$

$$= 2.791 \times 10^{-5} \times \frac{298\text{K}}{273\text{K}} \times \frac{101.325 \text{ kPa}}{103.19 \text{ kPa}}$$

$$= 3.0002 \times 10^{-5} \text{ L}$$

Since ppm is a volume ratio, we may write : $\text{ppm} = \dfrac{X \text{ L}}{10^6 \text{ L}} = \dfrac{V_{SO2}(\text{L})}{1000 \times V_{air}(\text{m}^3)}$
(ie 1ppm = 1L in 1000 m^3)

1m3 = 10^3 L

We have $V_{SO2\text{ -corr}}$(L) in 1 m^3 of air and so we have {1000 x $V_{SO2\text{ -corr}}$(L)} in {1000 x V_{air}(m^3)}.

ppmv = 1000 x $V_{SO2\text{ -corr}}$ = **0.0300 ppm of SO_2**