# Air Pollution I

## Air Pollution Concentration Units and Exercises

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# Air Pollution Concentration Units and Exercises

# Air Pollution Concentration
# Is expressed in Two main ways

**Mass Per Unit Volume**

- Mass of air pollutant per cubic meter of air
- Used for solid, liquid and gaseous air pollutants
- Grams per cubic meter ($g/m^3$)
- Milligrams per cubic meter ($mg/m^3$) = 0.001 $g/m^3$
- Micrograms per cubic meter ($\mu g/m^3$) = 0.001 $mg/m^3$ = $1.0 \times 10^{-6}$ $g/m^3$

**Parts Per Million (ppm)**

- No. of molecules of air pollutant per million molecules of air
- Used for gaseous air pollutants
- 1 part per billion (ppb) = 0.001 ppm
- 1 part per trillion (ppt) = 0.001 ppb = $1.0 \times 10^{-6}$ ppm

# Exercise 1

Express the following situations in terms of the air pollution concentration

1. 500 mg of carbon monoxide in a 3 m x 3 m x 3 m room
2. 10 milligrams of ozone in a 1000 cubic-meter warehouse

# Solution

1. 500 mg of carbon monoxide in a 3 m x 3 m x 3 m room =

   500 mg/27 $m^3$ = 18.52 mg/$m^3$

2. 10 milligrams of ozone in a 1000 cubic-meter warehouse =

   10 mg/1000 $m^3$ = 0.01 mg/$m^3$ = 10 µg/$m^3$

# Exercise 2

Are the concentration levels of Exercise 1 of concern in terms of air pollution?

For the threshold value, use the lowest

(i.e. most strict) 1-hour concentration standard

- For carbon monoxide the threshold value is 23 $mg/m^3$
- For ozone  the threshold value is 183 $\mu g/m^3$

# Solution

We looked at following situations …

1. 500 mg of carbon monoxide in a 3 m x 3 m x 3 m room = 18.52 $mg/m^3$.

   1-hour standard for carbon monoxide is 23 $mg/m^3$.

   Values are fairly close. Therefore,

   yes, carbon monoxide at this concentration level is of concern in terms of air pollution.

2. 10 milligrams of ozone in a 1000 cubic-meter warehouse= 10 $\mu g/m^3$.

   1-hour standard for ozone is 183 $\mu g/m^3$.

   Value is much less.

   Therefore, no, ozone at this concentration level is not of concern in terms of air pollution

# CONVERSION OF UNITS

- The mole (symbol: mol) is the unit of measurement for amount of substance in the International System of Units (SI). It is defined as exactly $6.02214076 \times 10^{23}$ particles, which may be atoms, molecules, ions, or electrons.
- An amount of any substance in grams that is numerically equal to its atomic or molecular weight in atomic mass unit (amu) has been defined as one mole of that substance. By this definition, one mole of hydrogen is 2.016 grams, one mole of methane is 16.043 grams, and one mole of water is 18.015 grams.

# CONVERSION OF UNITS

- Molar volume at Standard conditions for Temperature and Pressure (STP) can be used to convert from moles to gas volume and from gas volume to moles. The equality of 1 mol=22.4L is the basis for the conversion factor
- STP-> T=0 $^{o}C$ P=1 atm (1013.25 mb)
- 1 Liter =1000 $cm^3$
- Molecular weight, also called molecular mass, mass of a molecule of a substance, based on 12 as the atomic weight of carbon-12. It is calculated in practice by summing the atomic weights of the atoms making up the substance's molecular formula.

# CONVERSION OF UNITS

- Sample Molecular Weight Calculation
- Using the periodic table of the elements to find atomic weights, we find that

- Hydrogen has an atomic weight of 1, and
- Oxygen's is 16.
- In order to calculate the molecular weight of one water molecule ($H_2O$), we add the contributions from each atom; that is,

2(1) + 1(16) = 18 grams/mole.

# Problems and Homework

## Problem 1

An $SO_2$ concentration is given as 830 μg/m$^3$ at 25°C and 1 atm. Express this concentration in parts per million (ppm). The molecular weight of $SO_2$ is 64 g/mol and 1 mol=22.4 L at STP.

**Solution**

Concentration of $SO_2$ is 830 μg/m$^3$

Molecular Weight of $SO_2$ is 64g/mol

$$P_1V_1T_2 = P_2V_2T_1$$

$$1 \times 22.4\left(\frac{L}{mol}\right) \times (25 + 273)K = 1 \times V_2 \times 273K$$

$$V_2 = \frac{22.4\left(\frac{L}{mol}\right) \times 298\ K}{273\ K} = 24.5\ \left(\frac{L}{mol}\right)$$

$$Concentration\ (ppm) = \frac{concentration\ \left(\frac{\mu g}{m^3}\right) \times volume\left(\frac{L}{mol}\right)}{molecular\ weight\ \left(\frac{g}{mol}\right) \times 1000\left(\frac{\mu g L}{m^3 g}\right)}$$

$$Concentration\ (ppm) = \frac{830\ \left(\frac{\mu g}{m^3}\right) \times 24.5\left(\frac{L}{mol}\right)}{64\left(\frac{g}{mol}\right) \times 1000\left(\frac{\mu g L}{m^3 g}\right)} = 0.32\ ppm$$

**Problem 2:**

The exhaust from a 1981 Honda contains 1.5% by volume of carbon monoxide. Compute the concentration of CO in milligrams/m$^3$ at 25°C and 1 atm of pressure. The molecular weight of CO is28 g/mol and 1 mol=22.4 L at STP.

**Solution:**

1 percent by volume = $10^4$ ppm.

1.5 percent by volume = 1.5*$10^4$ ppm.

Molecular Weight of CO is 28 g/mol.

$$P_1V_1T_2 = P_2V_2T_1$$

$$1 \times 22.4\left(\frac{L}{mol}\right) \times (25+273)K = 1 \times V_2 \times 273K$$

$$V_2 = \frac{22.4\left(\frac{L}{mol}\right) \times 298\ K}{273\ K} = 24.45\ \left(\frac{L}{mol}\right)$$

$$Concentration\ \left(\frac{\mu g}{m^3}\right) = \frac{ppm \times\ molecular\ weight\ \left(\frac{g}{mol}\right) \times 1000\left(\frac{\mu g L}{m^3 g}\right)}{volume\left(\frac{L}{mol}\right)}$$

$$Concentration\ \left(\frac{\mu g}{m^3}\right) = \frac{1.5\times10^4 \times 28\ \left(\frac{g}{mol}\right)\times1000\left(\frac{\mu g L}{m^3 g}\right)}{24.45\left(\frac{L}{mol}\right)} = 1.72 \times 10^7\ \left(\frac{\mu g}{m^3}\right) = 1.72 \times 10^4\ \left(\frac{mg}{m^3}\right)$$

# Homework

1. Carbon Monoxide concentration at 90°C and 6 atm is 90 μg/$m^3$. Express this concentration in ppm. The molecular Weight of CO is 28 g/mol and 1 mol=22.4 L at STP.
2. An exhaust gas containing 3.2 percent by volume $SO_2$ is released at 25°C and 1 atm. Compute the concentration in mg/$m^3$. The molecular Weight of $SO_2$ is 64 g/mol and 1 mol=22.4 L at STP.