The Case of the
DISABLING BREATH

By Mitch Ricketts

Math Toolbox is designed to help readers apply STEM principles to everyday safety issues. Many readers may feel apprehensive about math and science. This series employs various communication strategies to make the learning process easier and more accessible.

Chemical exposures result in hundreds of deaths and thousands of nonfatal injuries in U.S. workplaces each year (BLS, n.d.). Figure 1 illustrates one such case in which a worker suffered permanent debilitating injuries from a few breaths of a very high concentration of airborne ammonia.

Hazardous gases and vapors are often categorized according to their toxic effects (Henretig et al., 2019). For example, primary respiratory irritants such as ammonia and chlorine may cause direct physical injury to mucous membranes and other tissues in the respiratory system. Systemic toxins such as carbon monoxide may interfere with the body's ability to use oxygen, or they may affect other physiological systems and organs throughout the body, as in the case of benzene overexposure. As a final example, simple asphyxiants such as nitrogen may have little toxicity of their own but create oxygen-deficient environments when present in high concentrations.

Safety professionals are often faced with the task of interpreting air monitoring reports. For gases and vapors, airborne concentrations may be reported in mass-based units (e.g., milligrams per cubic meter, mg/m^3) or in volume-based units (e.g., parts per million, ppm). In this article, we will consider how these units of measure are related.

Mass- & Volume-Based Units of Measure

We may quantify an airborne gas or vapor concentration as a ratio of the contaminant's mass per unit volume of air. To illustrate, imagine that an air sample indicates 20 milligrams (20 mg) of a gas is dispersed in 0.1 cubic meters (0.1 m^3) of dry air. The formula for calculating the concentration as milligrams per cubic meter (mg/m^3) is:

$$mg/m^3 = \frac{milligrams\ of\ contaminant}{cubic\ meters\ of\ air}$$

If we insert the values from the air sample (20 mg of the gas in 0.1 m^3 of air), we find the mass-based concentration of the gas is 200 mg/m^3:

$$mg/m^3 = 20 \div 0.1 = 200$$

Similarly, if a sample indicates that 480 milligrams of a gas is dispersed in 12 cubic meters of air, the concentration is 40 mg/m^3, as follows:

$$mg/m^3 = 480 \div 12 = 40$$

As an alternative unit of measure, we may quantify airborne concentrations of gases and vapors based on the volume of the contaminant. Volume-based concentrations are commonly stated as parts of the contaminant per million parts of the total mixture (parts per million, ppm). The formula for ppm is:

$$ppm = \frac{volume\ of\ contaminant}{total\ volume\ of\ mixture} \times 1{,}000{,}000$$

As an example, imagine 0.45 m^3 of a gas is dispersed throughout a volume of 300 m^3 of air. The volume-based concentration is 1,500 ppm because:

$$ppm = 0.45 \div 300 \times 1{,}000{,}000 = 1{,}500$$

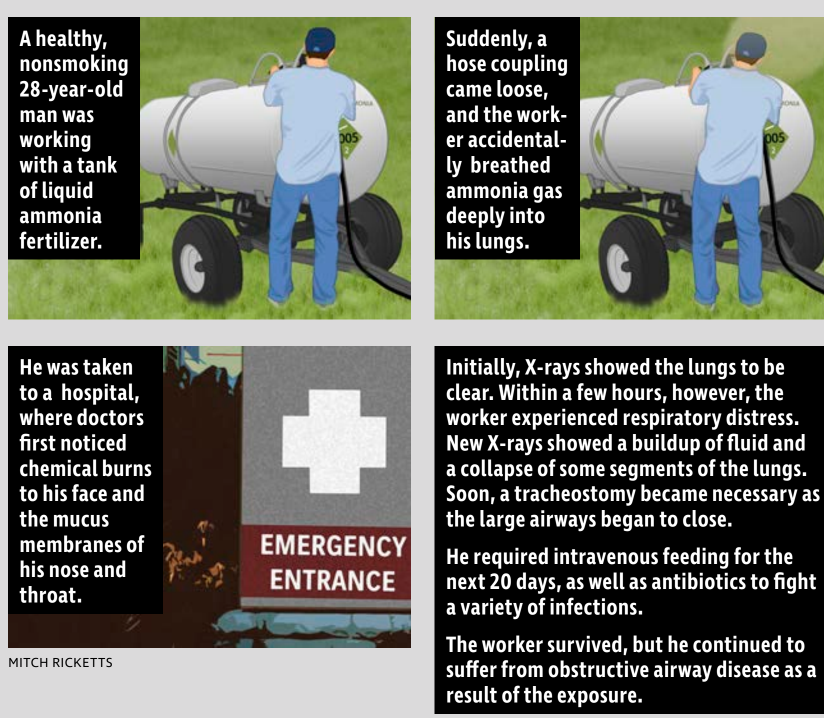
Likewise, 0.0006 m^3 of a gas dispersed throughout 5 m^3 of dry air equals 120 ppm:

$$ppm = 0.0006 \div 5 \times 1{,}000{,}000 = 120$$

Converting Between Volume- & Mass-Based Concentrations

Imagine that we know the airborne concentration of a contaminant in ppm, but we also wish to know the concentration in mg/m^3. We can easily make this conversion

FIGURE 1
ACUTE AMMONIA EXPOSURE CAUSES PERMANENT INJURY, CALIFORNIA



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Note. Adapted from "Radionuclidic Lung-Imaging Procedures in the Assessment of Injury Due to Ammonia Inhalation," by G.V. Taplin, S. Chopra, R.L. Yanda and D. Elam, 1976, *CHEST, 69*(5), 582-586.

if we have reason to believe the airborne contaminant will behave as an ideal gas.

For everyday workplace calculations, it is standard practice to treat many gases and vapors as ideal gases. There are some exceptions because the ideal gas law breaks down at high pressures (as in compressed gas containers) and at low temperatures (especially near temperatures that induce a change between the liquid and gas phases of a contaminant). The ideal gas law may also fail for certain substances such as water vapor and for heavy gases such as refrigerants.

Conversions between mass- and volume-based concentrations are possible because in everyday environments, one mole of any ideal gas will occupy the same volume as one mole of any other ideal gas (including the gas mixture that comprises dry air). Since the mole is a mass-based quantity, we can convert if we know the molecular weight of the contaminant.

Converting From ppm to mg/m³ at Normal Temperature & Pressure

Let's begin our conversions with a simplified equation that assumes air sampling occurs under conditions of normal temperature and pressure, which is equal to an ambient air temperature of 25 °C and a barometric pressure of 760 mmHg. [Note: Remember that normal temperature and pressure differs from standard temperature and pressure. Under conditions of standard temperature and pressure, ambient air temperature is 0 °C and barometric pressure is 760 mmHg. Under yet another set of conditions known as ventilation-based standard air, ambient air temperature is 21.1 °C, barometric pressure is 760 mmHg and air is specified as being completely dry (water concentration = 0.0 ppm). To convert ppm and mg/m^3 under conditions of standard temperature and pressure and ventilation-based standard air, use the generalized formulas discussed later in this article.] Later, we will consider a generalized equation for conditions involving different temperatures and pressures.

At normal temperature and pressure, one mole of any ideal gas occupies a volume of about 24.45 liters. Under these conditions, we convert from ppm to mg/m^3 with the formula:

$$mg/m^3 = \frac{ppm \cdot MW}{24.45}$$

where:

mg/m^3 = concentration of the gas/vapor mixture by mass, in milligrams of the substance per cubic meter of dry air

ppm = concentration of the gas/vapor mixture by volume, in parts of the substance per million parts of the total air/contaminant mixture

MW = molecular weight (i.e., molar mass) of the contaminant gas or vapor in atomic mass units (amu)

24.45 = volume (in liters, L) occupied by one gram-mole of an ideal gas at normal temperature and pressure (25 °C and 760 mmHg)

Let's consider the case described in Figure 1 (p. 43). The airborne concentration of ammonia was unknown in this case. However, since the worker suffered serious injury, it is possible that he breathed a concentration exceeding the level considered immediately dangerous to life and health (IDLH). The IDLH is the maximum concentration of a substance from which a worker can be expected to escape without injury, irreversible health effects or temporary effects that might prevent escape (NIOSH, n.d). For our first conversion, we will determine the concentration of ammonia in mg/m^3 that is considered IDLH.

Calculated example. The IDLH concentration for ammonia is 300 ppm (NIOSH, n.d.). This means the type of injury experienced by the worker in Figure 1 (p. 43) is most likely to occur at exposures above 300 ppm.

To convert from ppm to mg/m^3, we must know the molecular weight of ammonia. According to the National Institute for Standards and Technology (NIST, n.d.), the molecular weight of ammonia is 17.0305 amu.

The data needed for the conversion can be summarized as follows:

- The IDLH for ammonia is 300 ppm. This is the value of ppm in the formula.
- The molecular weight of ammonia is 17.0305 amu. This is the value of MW in the formula.

Based on these data, we can calculate the IDLH of ammonia in units of mg/m^3.

Step 1: Start with the equation:

$$mg/m^3 = \frac{ppm \cdot MW}{24.45}$$

Step 2: Insert the known values for volume-based concentration (ppm = 300) and molecular weight (MW = 17.0305 amu). Then solve for mg/m^3:

$$mg/m^3 = \frac{300 \cdot 17.0305}{24.45} = 208.96$$

(rounded two places past the decimal)

Step 3: Our calculation indicates that the IDLH for ammonia is approximately 209 mg/m^3 assuming normal temperature and pressure.

Alternate example. Let's calculate an example for a different gas, carbon monoxide. This time, we'll convert the NIOSH recommended exposure limit as a daily time-weighted average (REL-TWA).

The REL-TWA concentration for carbon monoxide is 35 ppm (NIOSH, n.d.). This means it is recommended that a worker's exposure to carbon monoxide be limited to a time-weighted average concentration of no more than 35 ppm for up to a 10-hr workday during a 40-hr workweek. The molecular weight of carbon monoxide is 28.0101 amu (NIST, n.d.). Based on these data, we can calculate the REL-TWA of carbon monoxide in units of mg/m^3.

Step 1: The equation is:

$$mg/m^3 = \frac{ppm \cdot MW}{24.45}$$

Step 2: Insert the known values for volume-based concentration (ppm = 35) and molecular weight (MW = 28.0101 amu). Then solve for mg/m^3:

$$mg/m^3 = \frac{35 \cdot 28.0101}{24.45} = 40.10$$

(which NIOSH further rounds to 40 mg/m^3)

Step 3: The calculation indicates that the mass-based concentration of about 40 mg/m^3 is equivalent to the volume-based concentration of 35 ppm as the REL-TWA for carbon monoxide at normal temperature and pressure.

You Do the Math

Apply your knowledge to the following questions. Answers are on p. 51.

1. The recommended exposure limit as a ceiling concentration (REL-C) for ozone is 0.1 ppm (NIOSH, n.d.). This means it is recommended that a worker's exposure to ozone should never exceed an instantaneous concentration 0.1 ppm. The molecular weight of ozone is 47.9982 amu (NIST, n.d.). Based on these data, calculate the REL-C of ozone in units of mg/m^3 assuming normal temperature and pressure.
2. The IDLH concentration for nitric oxide is 100 ppm (NIOSH, n.d.). The molecular weight of nitric oxide is 30.0061 amu (NIST, n.d.). Based on these data, calculate the IDLH concentration for nitric oxide in units of mg/m^3 assuming normal temperature and pressure.

Converting From mg/m³ to ppm at Normal Temperature & Pressure

In previous calculations, we converted from volume-based to mass-based concentrations. Let's now solve the opposite problem and convert from mg/m³ to ppm. We rearrange the equation to solve for ppm as follows:

Start with the original formula.

$$mg/m^3 = \frac{ppm \cdot MW}{24.45}$$

Multiply both sides of the formula by 24.45.

$$mg/m^3 \cdot 24.45 = \frac{ppm \cdot MW}{24.45} \cdot 24.24$$

Cross through the terms that cancel out.

$$mg/m^3 \cdot 24.45 = \frac{ppm \cdot MW}{\cancel{24.45}} \cdot \cancel{24.24}$$

Eliminate the canceled terms.

$$mg/m^3 \cdot 24.45 = ppm \cdot MW$$

Divide both sides by *MW*.

$$\frac{mg/m^3 \cdot 24.45}{MW} = \frac{ppm \cdot MW}{MW}$$

Cross through the terms that cancel out.

$$\frac{mg/m^3 \cdot 24.45}{MW} = \frac{ppm \cdot \cancel{MW}}{\cancel{MW}}$$

Eliminate the canceled terms.

$$\frac{mg/m^3 \cdot 24.45}{MW} = ppm$$

Rearrange, and use the resulting equation:

$$ppm = \frac{mg/m^3 \cdot 24.45}{MW}$$

Example. The NIOSH (n.d.) recommended short-term exposure limit (REL-ST) for nitrogen dioxide is 1.8 mg/m³. This means it is recommended that a worker's exposure to nitrogen dioxide should never exceed a 15-min TWA concentration of 1.8 mg/m³. The molecular weight of nitrogen dioxide is 46.0055 amu (NIST, n.d.).

We calculate the REL-ST of nitrogen dioxide in units of ppm using the rearranged formula.

Step 1: The equation is:

$$ppm = \frac{mg/m^3 \cdot 24.45}{MW}$$

Step 2: Insert the known values for mass-based concentration (mg/m³ = 1.8) and molecular weight (*MW* = 46.0055 amu). Then solve for ppm:

$$ppm = \frac{1.8 \cdot 24.45}{46.0555} = 0.96$$

(which NIOSH further rounds to 1 ppm)

Step 3: The calculation indicates that the volume-based concentration of about 1 ppm is equivalent to the mass-based concentration of 1.8 mg/m³ as the REL-ST for nitrogen dioxide at normal temperature and pressure.

Alternate example. This time, let's imagine we have measured an airborne phosphine concentration of 0.4 mg/m³ as a TWA. The molecular weight of phosphine is 33.9976 amu (NIST, n.d.). Based on these data, we will convert the concentration of phosphine to units of ppm.

Step 1: The equation is:

$$ppm = \frac{mg/m^3 \cdot 24.45}{MW}$$

Step 2: Insert the known values for mass-based concentration (mg/m³ = 0.4) and molecular weight (*MW* = 33.9976 amu). Then solve for ppm:

$$ppm = \frac{0.4 \cdot 24.45}{33.9976} = 0.29$$

(which NIOSH further rounds to 0.3 ppm)

Step 3: The calculation indicates the volume-based concentration of about 0.3 ppm is equivalent to the mass-based concentration of 0.4 mg/m³ for phosphine.

You Do the Math

Apply your knowledge to the following questions. Answers are on p. 51.

3. The REL-TWA for carbon dioxide is 9,000 mg/m³ (NIOSH, n.d.). The molecular weight of carbon dioxide is 44.0095 amu (NIST, n.d.). Based on these data, calculate the REL-TWA for carbon dioxide in units of ppm assuming normal temperature and pressure.

4. Imagine we have measured an airborne fluorine concentration of 0.2 mg/m³ as a TWA. The molecular weight of fluorine is 37.9968 amu (NIST, n.d.). Based on these data, convert the fluorine concentration of 0.2 mg/m³ to units of ppm assuming normal temperature and pressure.

Converting When Conditions Differ From Normal Temperature & Pressure

Our previous calculations were based on the volume of one mole of an ideal gas at an ambient temperature and barometric pressure of 25 °C and 760 mmHg, respectively. When conditions differ, we can use more general formulas that remain valid for any ambient temperatures or pressures at which the contaminant behaves as an ideal gas. In these situations, the formulas can be stated as follows (Finucane, 2006):

$$mg/m^3 = \frac{ppm \cdot MW \cdot P_{mmHg}}{62.36 \cdot T_K}$$

and

$$ppm = \frac{mg/m^3 \cdot 62.36 \cdot T_K}{MW \cdot P_{mmHg}}$$

where:

mg/m³ = concentration of the gas/vapor mixture by mass in milligrams of the substance per cubic meter of dry air

ppm = concentration of the gas/vapor mixture by volume in parts of the substance per million parts of the total air/contaminant mixture

MW = molecular weight of the contaminant gas or vapor in amu

T_K = absolute temperature in degrees Kelvin (°K)

P_{mmHg} = absolute barometric pressure in mmHg; note: for concentrations in the ambient air, absolute pressure is simply the pressure of the atmosphere; for concentrations in sealed vessels, absolute pressure is the sum of atmospheric pressure and gauge pressure within the vessel.

62.36 = conversion factor for volume in liters (L) occupied by one gram-mole of an ideal gas when temperature is specified in Kelvin and pressure is specified in mmHg, absolute; for calculations based on metrics other than liters, grams, Kelvin and mmHg, consult standard charts for the universal gas constant.

Calculated example: Converting from ppm to mg/m³ at actual temperature and pressure. In this example, we'll convert from a volume-based to a mass-based concentration. Imagine the airborne concentration of acetylene is 250 ppm in a workplace where the ambient temperature is 20 °C and the absolute barometric pressure is 730 mmHg. The molecular weight of acetylene is 26.0373 amu (NIST, n.d.). Our equation requires that we first convert the ambient temperature to degrees Kelvin. The formula for converting from Celsius to Kelvin is:

$$T_K = T_C + 273$$

where:

T_K = absolute temperature in degrees Kelvin

T_C = temperature in degrees Celsius

In this example, the temperature of 20 °C is equal to 293 °K, as follows:

$$T_K = 20 + 273 = 293$$

We may now convert from ppm to mg/m³ based on the following data:

- The measured airborne concentration of acetylene is 250 ppm. This is the value of ppm in the formula.

•The molecular weight of acetylene is 26.0373 amu. This is the value of MW in the formula.

•The ambient absolute temperature is 293 °K. This is the value of T_K.

•The absolute barometric pressure is 730 mmHg. This is the value of P_{mmHg}.

The procedure for converting is as follows.

Step 1: Start with the equation:

$$mg/m^3 = \frac{ppm \cdot MW \cdot P_{mmHg}}{62.36 \cdot T_K}$$

Step 2: Insert the known values for the volume-based concentration (ppm = 250), molecular weight (MW = 26.0373 amu), absolute temperature (T_K = 293 °K), and absolute pressure (P_{mmHg} = 730 mmHg). Then solve for mg/m³.

$$mg/m^3 = \frac{250 \cdot 26.0373 \cdot 730}{62.36 \cdot 293} = 260.07$$
(rounded)

Step 3: Our calculation indicates that the measured acetylene concentration is approximately 260 mg/m³ based on the actual temperature and pressure in the workplace. For comparison, the result would have been about 266 mg/m³ if we had based the calculation on normal temperature and pressure (you can confirm this using the original equation for conversions at 25 °C and 760 mmHg).

Calculated example: Converting from mg/m³ to ppm at actual temperature and pressure. This time, we'll make the opposite conversion, from a mass-based to a volume-based concentration. Imagine the airborne concentration of hydrogen chloride is 6 mg/m³ in a workplace where the ambient temperature is 31 °C and the absolute barometric pressure is 770 mmHg. The molecular weight of hydrogen chloride is 36.4610 amu (NIST, n.d.).

Remember that we need to convert our temperature of 31 °C to degrees Kelvin. Absolute temperature in this case is 304 °K because:

$$T_K = 31 + 273 = 304$$

We may summarize the data as follows:

•The measured airborne concentration of hydrogen chloride is 6 mg/m³. This is the value of mg/m³ in the formula.

•The molecular weight of hydrogen chloride is 36.4610 amu. This is the value of MW in the formula.

•The ambient absolute temperature is 304 °K. This is the value of T_K.

•The absolute barometric pressure is 770 mmHg. This is the value of P_{mmHg}.

We can now proceed with the conversion.

Step 1: The equation is:

$$ppm = \frac{mg/m^3 \cdot 62.36 \cdot T_K}{MW \cdot P_{mmHg}}$$

Step 2: Insert the known values for mass-based concentration (mg/m³ = 6), molecular weight (MW = 36.4610 amu), absolute temperature (T_K = 304 °K) and absolute pressure (P_{mmHg} = 770 mmHg). Then solve for ppm:

$$ppm = \frac{6 \cdot 62.36 \cdot 304}{36.4610 \cdot 770} = 4.05$$
(rounded)

Step 3: Our calculation indicates that the measured hydrogen chloride concentration is approximately 4 ppm based on the actual temperature and pressure in the workplace. (The result would have been a nearly identical 4.02 ppm if we had based the calculation on a normal temperature and pressure of 25 °C and 760 mmHg.)

You Do the Math

Apply your knowledge to the following questions. Answers are on p. 51.

5. Imagine that the airborne concentration of ammonia is 173 ppm in a workplace where the ambient temperature is 29 °C and the absolute barometric pressure is 769 mmHg. The molecular weight of ammonia is 17.0305 amu (NIST, n.d.). Calculate the absolute ambient temperature and the mass-based airborne concentration of ammonia as follows:

a. What is the absolute temperature in degrees Kelvin? Use the equation for converting from Celsius to Kelvin.

b. What is the mass-based concentration of ammonia? Use the formula for converting from ppm to mg/m³ at actual temperature and pressure. Solve for concentration in mg/m³.

6. Imagine that the airborne concentration of propane is 1,200 mg/m³ in a workplace where the ambient temperature is 17 °C and the absolute barometric pressure is 735 mmHg. The molecular weight of propane is 44.0956 amu (NIST, n.d.). Calculate the absolute ambient temperature and the volume-based airborne concentration of propane as follows:

a. What is the absolute temperature in degrees Kelvin? Use the equation for converting from Celsius to Kelvin.

b. What is the volume-based concentration of propane? Use the formula for converting from mg/m³ to ppm at actual temperature and pressure. Solve for concentration in ppm.

Concluding Comments

We may convert between volume- and mass-based air concentrations under circumstances when airborne contaminants behave in accordance with the ideal gas law. This is because one mole of any ideal gas will occupy a known volume when pressure and temperature are held constant. A reasonable estimate can be obtained in many workplaces when we use a gas conversion factor of 24.45 because this is the volume in liters that is occupied by one gram-mole of an ideal gas at an ambient temperature of 25 °C (77 °F) and a barometric pressure of 760 mmHg.

For more precise calculations, we may use different gas conversion factors that more closely match the environmental conditions of the workplace. Specifically, to convert at any desired temperature and pressure, we can use the last two equations, with 62.36 as the gas conversion factor, providing that we enter absolute temperature in degrees Kelvin and absolute pressure in mmHg. Readers may consult tables of the universal gas constant for conversion factors when absolute temperature and pressure are expressed in other units.

The equations we have examined are valid only when contaminants behave as ideal gases. Specific conditions that may lead to false results include high pressures, as in compressed gas containers, and very low temperatures, particularly at temperatures near the contaminant's condensation temperature. Furthermore, the calculations may be inaccurate for water vapor and for heavy gases such as refrigerants.

How Much Have I Learned?

Try these problems on your own. Answers are on p. 51.

7. The IDLH concentration for oxygen difluoride is 0.5 ppm (NIOSH, n.d.). The molecular weight of oxygen difluoride is 53.9962 amu (NIST, n.d.). Based on these data, calculate the IDLH concentration for oxygen

difluoride in mg/m³ assuming normal temperature and pressure.

8. The REL-C for ethylene oxide is 9 mg/m³ (NIOSH, n.d.). The molecular weight of ethylene oxide is 44.0526 amu (NIST, n.d.). Based on these data, calculate the REL-C for ethylene oxide in ppm assuming normal temperature and pressure.

9. Imagine the airborne concentration of nitrogen dioxide is 8 ppm in a workplace where the ambient temperature is 14 °C and the absolute barometric pressure is 740 mmHg. The molecular weight of nitrogen dioxide is 46.0055 amu (NIST, n.d.). Calculate the absolute ambient temperature and the mass-based airborne concentration of nitrogen dioxide as follows:

a. What is the absolute temperature in degrees Kelvin? Use the equation for converting from Celsius to Kelvin.

b. What is the mass-based concentration of nitrogen dioxide? Use the formula for converting from ppm to mg/m³ at actual temperature and pressure. Solve for concentration in mg/m³.

10. Imagine that the airborne concentration of carbon monoxide is 53 mg/m³ in a workplace where the ambient temperature is 32 °C and the absolute barometric pressure is 772 mmHg. The molecular weight of carbon monoxide is 28.0101 amu (NIST, n.d.). Calculate the absolute ambient temperature and the volume-based airborne concentration of carbon monoxide as follows:

a. What is the absolute temperature in degrees Kelvin? Use the equation for converting from Celsius to Kelvin.

b. What is the volume-based concentration of carbon monoxide? Use the formula for converting from mg/m³ to ppm at actual temperature and pressure. Solve for concentration in ppm. **PSJ**

References

Bureau of Labor Statistics (BLS). (n.d.). Occupational injuries and illnesses and fatal injuries profiles. www.bls.gov/iif/data.htm

Finucane, E.W. (2006). *Definitions, conversions and calculations for occupational safety and health professionals* (3rd ed.). CRC Press.

Henretig, F.M., Kirk, M.A. & McKay Jr., C.A. (2019). Hazardous chemical emergencies and poisonings. *New England Journal of Medicine, 380*(17), 1638-1655. https://doi.org/10.1056/NEJMra1504690

National Institute for Standards and Technology (NIST). (n.d.). NIST chemistry webbook. https://webbook.nist.gov/chemistry

NIOSH. (n.d.). NIOSH pocket guide to chemical hazards. www.cdc.gov/niosh/npg/default.html

Taplin, G.V., Chopra, S., Yanda, R.L. & Elam, D. (1976). Radionuclidic lung-imaging procedures in the assessment of injury due to ammonia inhalation. *CHEST, 69*(5), 582-586. https://doi.org/10.1378/chest.69.5.582

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Math Toolbox, continued from pp. 43-47

Answers: The Case of the Disabling Breath

You Do the Math

Your answers may vary slightly due to rounding.

1. $\frac{mg}{m^3} = \frac{0.1 \cdot 47.9982}{24.45} = 0.20$ (rounded)

2. $\frac{mg}{m^3} = \frac{100 \cdot 30.0061}{24.45} = 122.72$ (rounded)

3. $ppm = \frac{9{,}000 \cdot 24.45}{44.0095} = 5{,}000.06$ (which NIOSH further rounds to 5,000)

4. $ppm = \frac{0.2 \cdot 24.45}{37.9968} = 0.13$ (which NIOSH further rounds to 0.1)

5.a. $T_K = 29 + 273 = 302$

5.b. $mg/m^3 = \frac{173 \cdot 17.0305 \cdot 769}{62.36 \cdot 302} = 120.31$ (rounded)

6.a. $T_K = 17 + 273 = 290$

6.b. $ppm = \frac{1{,}200 \cdot 62.36 \cdot 290}{44.0956 \cdot 735} = 669.58$ (rounded)

How Much Have I Learned?

7. $mg/m^3 = \frac{0.5 \cdot 53.9962}{24.45} = 1.10$ (rounded)

8. $ppm = \frac{9 \cdot 24.45}{44.0526} = 5.0$ (rounded)

9.a. $T_K = 14 + 273 = 287$

9.b. $\frac{mg}{m^3} = \frac{8 \cdot 46.0055 \cdot 740}{62.36 \cdot 287} = 15.22$ (rounded)

10.a. $T_K = 32 + 273 = 305$

10.b. $ppm = \frac{53 \cdot 62.36 \cdot 305}{28.0101 \cdot 772} = 46.62$ (rounded)