$$M_{gas} = 34.0 \text{ g/mol}$$

The molar mass of the gas sample is 34.0 g/mol.

(b) If the compound has the formula XH_3, where H represents hydrogen, then the atomic molar mass of "X" must be (34.0 − 3(1.01)) g/mol, which gives 31.0 g/mol. The atom must be phosphorus, P, which is 31.0 g/mol if rounded to 3 digits, and the gas is therefore $PH_{3(g)}$.

9.5 AIR QUALITY

PRACTICE

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Understanding Concepts

1. The percentage composition by volume of water vapour in air varies widely.
2. The nitrogen in the atmosphere is converted to soluble compounds (useful to plants) by lightning and by nitrogen-fixing bacteria. During decay of the plants (or the animals that ate them) other bacteria convert the nitrogen back to elemental form and release it to the atmosphere.
3. Use of the internal combustion engine is the most significant human activity contributing nitrogen oxides to the atmosphere.
4. Nitrogen dioxide may be decomposed by ultraviolet (UV) light to produce nitrogen oxide and oxygen.

$$NO_{2(g)} \xrightarrow{\text{UV light}} NO_{(g)} + O_{(g)}$$

The atomic oxygen reacts with molecular oxygen to produce ground-level ozone which is toxic to humans.

$$O_{(g)} + O_{2(g)} \rightarrow O_{3(g)}$$

5. (a) Find the total amount of gases in 240 kL of air at SATP:

$$n_{air} = ?$$
$$p = 100 \text{ kPa}$$
$$T = 25°\text{C} = 298 \text{ K}$$
$$v = 240 \text{ kL}$$
$$R = 8.31 \text{ kPa·L/(mol·K)}$$

$$pv = nRT$$
$$n_{air} = \frac{pv}{RT}$$
$$= \frac{100 \cancel{\text{kPa}} \times 240 \text{ k}\cancel{\text{L}}}{\frac{8.31 \cancel{\text{kPa}}\cdot\cancel{\text{L}}}{\text{mol}\cdot\cancel{\text{K}}} \times 298 \cancel{\text{K}}}$$
$$n_{air} = 9.69 \text{ kmol}$$

Then, using percentage composition values from Table 1:

$$n_{N2} = 9.69 \text{ kmol} \times 0.7808$$
$$= 7.57 \text{ kmol}$$
$$n_{O2} = 9.69 \text{ kmol} \times 0.2095$$
$$= 2.03 \text{ kmol}$$
$$n_{Ar} = 9.69 \text{ kmol} \times 0.00934$$

$$= 90.5 \text{ mol}$$

$$n_{CO_2} = 9.69 \text{ kmol} \times 0.00036$$

$$= 3.5 \text{ mol}$$

The amounts of gases present in the air sample are: 7.57 kmol N_2, 2.03 kmol O_2, 90.5 mol Ar, and 3.5 mol CO_2.

(b) The masses of gases in the room are, respectively,

$$m_{N_2} = 7.57 \text{ k}\cancel{\text{mol}} \times \frac{28.02 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{N_2} = 212 \text{ kg}$$

The mass of nitrogen is 212 kg.

$$m_{O_2} = 2.03 \text{ k}\cancel{\text{mol}} \times \frac{32.00 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{O_2} = 65.0 \text{ kg}$$

The mass of oxygen is 65.0 kg.

$$m_{Ar} = 90.5 \cancel{\text{mol}} \times \frac{39.95 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{Ar} = 3.62 \times 10^3 \text{ g} = 3.62 \text{ kg}$$

The mass of argon is 3.62 kg.

$$m_{CO_2} = 3.5 \cancel{\text{mol}} \times \frac{44.01 \text{ g}}{1 \cancel{\text{mol}}}$$

$$m_{CO_2} = 1.5 \times 10^2 \text{ g} = 0.15 \text{ kg}$$

The mass of carbon dioxide is 0.15 kg.

The total mass of gases in the classroom is over 280 kg — impossible for most students to carry!

(c) After an hour with a class present, the amount of oxygen in the room should decrease, and the amounts of carbon dioxide and water vapour should increase, due to respiration and perspiration. This assumes that the room is not open to the outside atmosphere.

(d) $n_{O_2} = ?$ (consumed)

$p = 100$ kPa

$T = 25°\text{C} = 298$ K

$v = 30 \times 400 \text{ L} = 12\ 000$ L (precision rule)

$R = 8.31$ kPa·L/(mol·K)

$$pv = nRT$$

$$n_{O_2} = \frac{pv}{RT}$$

$$= \frac{100 \cancel{\text{kPa}} \times 12\ 000 \cancel{\text{L}}}{\frac{8.31 \cancel{\text{kPa}}\cdot\cancel{\text{L}}}{\text{mol}\cdot\cancel{\text{K}}} \times 298 \cancel{\text{K}}}$$

$$n_{O_2} = 0.485 \text{ kmol}$$

$$\text{percentage of } O_2 \text{ consumed} = \frac{0.485 \text{ k}\cancel{\text{mol}}}{2.03 \text{ k}\cancel{\text{mol}}} \times 100\ \%$$

$$\text{percentage of } O_2 \text{ consumed} = 23.9\ \%$$

In a day, 23.9% of the oxygen in the room would be consumed.
(Based upon the initial measurement of 25°C, the answer is 24%. Based upon the certainty of the values used in the calculation, the answer is 23.9%.)

6. An industry can purchase pollution “credits” from another industry that has reduced its own pollutant levels more than required.
   The process could be changed so the total emissions increase, but the increase is of non-polluting chemicals.
   If the industry increases production, the industry can claim a reduction of a pollutant by improving its process (reducing the emissions produced).

Making Connections

7. The air quality index (AQI) is a numerical system created in 1999 by the Environmental Protection Agency of the United States of America. It calculates a single pollution value by combining data on ozone, carbon monoxide, nitrogen dioxide, and particulate matter in the air. The particulate matter is measured for two areas — particles below 2.5 μm (microns) in size; and particles below 10 μm (microns) in size. These are called PM2.5 and PM10 in reports.

   The AQI is scaled as 0–50 (good — no cautions), 51–100 (moderate), and a new category from 1999, 101–150 (now designated *unhealthy if sensitive*), 151–200 (poor — limit exposure), and so on. The “unhealthy if sensitive” category refers to people with respiratory disease or serious allergies. The purpose of the AQI is to provide a single convenient referent number that citizens can use to rate air quality in their area.

   GO TO www.science.nelson.com, Chemistry 11, Teacher Centre.

Explore an Issue: Take a Stand: How Can We Improve the Air Quality in Our Communities?

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GO TO www.science.nelson.com, Chemistry 11, Teacher Centre.

(a) A sample letter:

Dear Mayor and Council Members:

Our research group in Dr. Lantz’s Chemistry 11 class at Air High has completed our preliminary study of air quality in our community. The design of our study was to obtain existing data from publications, reports, and the Internet and present that in the report attached.

Since starting the study we have become increasingly concerned with the quality of air in our community. Our initial hypothesis was that there is a correlation between the air quality and the number of asthmatic students in our school. We tested this hypothesis by gathering all of the information that we could about air quality. This included air quality indexes, relative humidity, and specific chemical concentrations over the last ten years.

As you might imagine, there are holes in the various databases as measurements of different chemicals to different precisions changed over time. The asthma database from local doctors and the hospitals was more complete as there is now government regulation that requires medical personnel to report all cases to a central authority. We tried to control for exercise-induced asthma in our study, but the lack of a full control reduces somewhat the confidence that we have in our preliminary results.

The data that we gathered was turned into evidence for the purpose of testing our hypotheses. As indicated in our report, the correlations between some of the air quality measures and the incidence of asthma were statistically significant only for natural components of the air — pollen and dust. In our study the change in air components from technological sources did not correlate significantly with the change in the incidence of asthma in our school.

Two high correlations that cannot be reported with confidence are the decrease of asthma for hockey players after switching from gasoline to propane fuel in our Zamboni, and the increase in asthma for those living near gasoline alley and the highway, where hydrocarbon air components are higher. The lack of confidence in these results is due to the low number of students in these samples.

Recognizing that our results are correlational and not causal, our recommendations based upon the statistically significant correlations in this one study are:

1. reduce the number of community flowers, grasses, and trees that produce pollen; and
2. reduce the dust created by oiling or paving the streets and roads.

Further correlational studies by students in future years can follow up on whether these measures are successful or not.

Based upon the low-confidence results for hockey players and students living in high hydrocarbon areas, we recommend that

3. the Zamboni continue to use propane rather than gasoline, but maybe even switch to battery power; and
4. a berm be built to protect students from hydrocarbon emissions from the gasoline being dispensed at the gas stations and partially burned gasoline being emitted from automobile exhausts.

Thank you for your attention to this matter. We are prepared to make an oral presentation to Council at any point in the future. If you see this type of report as being useful, our chemistry class would be willing to continue this work year after year.

Sincerely,

Dr. Lantz's Chemistry 11 class
cc. Principal C. Bisset

SECTION 9.5 QUESTIONS

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Understanding Concepts

1. The gases nitrogen, oxygen, argon, and carbon dioxide are the most abundant gases in air — ignoring water vapour.
2. Argon, neon, and krypton are the most abundant noble gases in air.
3. Water molecules are lighter than either oxygen or nitrogen molecules, so moist air should be less dense than dry air.
4. The three main air pollutants are noxious gases, such as sulfur dioxide; vapours from VOCs (volatile organic compounds); and heavy metals and carcinogens (primarily from coal combustion).
5. Ozone is not a primary air pollutant because it is produced secondarily from the reaction of nitrogen oxides and VOCs.
6. Catalytic converters reduce the emission of nitrogen oxide, carbon monoxide, and unburned hydrocarbon from car engines.
7. The most common strategies to reduce $NO_{x(g)}$ and VOC emissions involve reduced use of automobiles (car pools, public transport), and in general, any energy-saving strategy that reduces the burning of fossil fuels.

CHAPTER 9 SUMMARY

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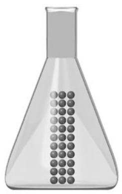
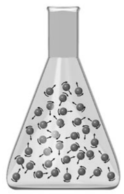
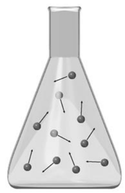
MAKE A SUMMARY

1. Empirical and Theoretical Properties of Solids, Liquids and Gases

State	Solid	Liquid	Gas
simple model	 solid (vibrational)	 liquid (vibrational, rotational and translational)	 gas (translational)
(a) empirical properties	definite shape and volume; virtually incompressible; does not flow easily	assumes the shape of the container but has a definite volume; virtually incompressible; flows easily	Assumes the shape and volume of the container; highly compressible; flows easily
(b) possible forces present (at SATP)	network covalent, ionic, intermetallic, and London plus (maybe) dipole and hydrogen bonding	intermetallic (e.g., $Hg_{(l)}$), and London plus (maybe) dipole-dipole and hydrogen bonding	van der Waal (dipole-dipole and London)
(c) type of motion of the particles	vibrational (mostly)	vibrational, rotational, and translational	translational (mostly)
(d) degree of order	least disordered	somewhat disordered	most disordered