Answer Key

Unit 5 Gases and Atmospheric Chemistry

Unit Preparation Questions (Assessing Readiness)

(Student textbook pages 496–9)

1. c

2. d

3. e

4. d

5. The combustion or burning of fossil fuels with insufficient air (oxygen).

6. A fume hood provides protection from exposure to hazardous or malodorous (smelly) gases or dusts while working with chemicals. The fumes or vapours are drawn up into the fume hood and away from the individual. Certain procedures may generate or require chemicals that are potentially poisonous or have a bad odour.

7. Precautions include: generate small amounts of gases; point the test tube away from people, on an angle away from the student; test using a splint placed *near the mouth* of the test tube.

8. Volatile liquids evaporate quickly. If flammable an open flame, or any source of a spark such as an electric motor or a light switch, could potentially ignite the vapour. Suggested precautions are: work in a fume hood if available; do not use near a lit Bunsen burner.

9. Turn off the gas immediately. Waft the gas from the area. Wait several minutes for the gas to dissipate before re-igniting.

10. As the gas is generated, the pressure in the container builds up. This could result in the stopper being blown off, or the container breaking due to built-up pressure.

11. c

12. e

13. b

14. c

15. e

16. e

17. b

18. Sample answer:

State	Compressibility	Viscosity	Molecular Motion	Distance Between Particles
solids	almost none	highest	slowest	usually least
liquids	slight	intermediate	intermediate	usually intermediate
gases	high	lowest	fastest	usually most

19. a. Diagrams should show particles with increased motion and the balloon increasing in volume, with greater spaces between the particles.

b. Diagrams should show particles with slower motion and the balloon decreasing in volume, with smaller spaces between the particles.

20. The order from bottom to top is: carbon dioxide, argon, oxygen, nitrogen, and helium.

21. Air is mainly composed of nitrogen, so the density of air will be closest to that of nitrogen.

22. One way is to change the temperature and allow the syringe to move. A second way is to decrease or increase the interior volume by pressing or pulling back the barrel of the syringe.

23. The density is 1562 g/L. Particles are much closer together in the solid state, so the density is greater than that of the gaseous state.

24. a. 0.114 mol/L **b.** 6.87×10^{22}

25. a. 3200 g **b.** 440 L

c. $d = 1.52$ g/L; higher than the value given at 25°C. Since density increases with a decrease in temperature, the temperature of the air must be below 25°C.

26. a. 1.799 g/L **b.** 17 g **c.** 4.2 L

d. density varies with temperature

27. a. As the temperature decreases, the density increases; an inverse relationship

b. 1.15 kg/m^3, 0.95 kg/m^3

c. 60°C, 155°C

d. Yes, in general, the densities of gases vary inversely with temperature.

28. c

29. e

30. a

31. d

32. a. $NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(g)$

b. $2NaCl(\ell) \rightarrow Cl_2(g) + 2Na(\ell)$

c. $MgCO_3(s) \rightarrow MgO(s) + CO_2(g)$

d. $2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(g)$

e. $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$

f. $2H_2O(\ell) \rightarrow O_2(g) + 2H_2(g)$

g. $(NH_4)_2CO_3(s) \rightarrow 2NH_3(g) + CO_2(g) + H_2O(\ell)$ *or* $H_2O(g)$

h. $FeS(s) + 2HCl(aq) \rightarrow H_2S(g) + FeCl_2(aq)$

i. $S(s) + O_2(g) \rightarrow SO_2(g)$

j. $2NI_3(s) \rightarrow N_2(g) + 3I_2(g)$

33. a. Use a piece of tubing to connect the flask (where the reaction is occurring) to the test tube, in which gas could be collected.

b. glowing splint test; if oxygen is present splint will burst into flames

34. a. $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ **b.** 1 mole to 2 moles

35. a. $C_8H_{18}(g) + 12.5O_2(g) \rightarrow 8CO_2(g) + 9H_2O(g)$

b. 95 kg **c.** 1.30×10^{27}

Chapter 11 Properties of Gases

Learning Check Questions

(Student textbook page 503)

1. The solid state of water is commonly called ice. The liquid state is always called water and the gaseous state is called water vapour or steam.

2. The stronger the attractive force, the more likely it is to be a solid or liquid at room temperature.

3. The molecules in gases are more random than in a liquid, and in solid the molecules are more ordered than in a liquid.

4. Intermolecular forces hold the molecules together in an orderly fashion; without them the molecules would be free to move about randomly. Without intermolecular forces all substances would be gases.

5. The average kinetic energy of the particles increases as you go from solid to liquid to gas.

6. Graphic organizers should distinguish between electrostatic attraction, interactions between polar molecules, and interactions between non-polar molecules.

(Student textbook page 510)

7. It is the force that a column of air exerts on the Earth's surface divided by the area of Earth's surface at the base of the column.

8. The height of mercury in a tube immersed in shallow dish of mercury was dependent on atmospheric pressure; the higher the atmospheric pressure, the higher the level of mercury in the tube.

9. a. 363 kPa **b.** 1.39 atm **c.** 1.0×10^2 kPa **d.** 6.3×10^4 Pa

10. number of bars = number of psi × (1.01325/14.7)

11. As altitude increases, atmospheric pressure decreases. This means there is less oxygen available for any given volume, such as a lung full, at a higher altitude and breathing may need to be assisted.

12. The force on the surface of the water in the pan due to atmospheric pressure is balanced by the pressure from the water in the bottle, which tends to push the water in the pan upward. When the water level in the pan falls below the water level in the bottle, the force from the water in the bottle is greater than the force due to atmospheric pressure, pushing the water level in the pan back up until it is level with the water in the bottle.

(Student textbook page 518)

13. For a given amount of gas at constant pressure the volume of a gas varies directly with the temperature expressed in K.

14. Absolute zero is the extrapolated value for the volume-temperature graph when the volume of the gas is zero–an impossible situation for real gases. Kelvin suggested that this temperature, –273.15°C, is the lowest possible temperature value. A new temperature scale was created with 0 K as the starting temperature.

15. Linear lines with common x-intercept at −273.15°C

16. a. 300 K **b.** 2.48×10^2 K

c. 100.0°C (0 degrees C is 273.2 K to one decimal)

d. −249.6°C

17. Volume of a gas is inversely related to pressure of gas (Boyle's Law) and it, therefore, represents another variable that will affect the study of the gas.

18. The balloon would quickly shrivel upon contact with the liquid nitrogen because molecular motion slows down as the temperature decreases and the volume of the gas decreases.

Caption Questions

Figure 11.1 (Student textbook page 503): Atoms of hydrogen and atoms of chlorine have different electronegativities, causing a permanent dipole effect.

Figure 11.5 (Student textbook page 505): Increasing temperature causes the average kinetic energy of molecules to increase. They strike the surface of a container more often and harder, causing the volume of a flexible container to increase.

Figure 11.7 (Student textbook page 508): As atmospheric pressure changes, the level of mercury in the tube changes. Greater pressure causes the mercury column to rise and lower atmospheric pressure causes the column to fall.

Figure 11.14 (Student textbook page 517): If the Celsius temperature is doubled, the Kelvin temperature is not doubled. Instead it goes up by the amount of the difference between the two Celsius temperatures.

Figure 11.15 (Student textbook page 519): The *x*-intercept for the Celsius graph is –273°C, and the *y*-intercept varies depending on initial pressure and volume. The *x*-and *y*-intercepts for the Kelvin graph are both 0.

Figure 11.17 (Student textbook page 523): A relief valve is a safety device to prevent the cylinder from exploding. At a critical pressure the relief valve opens and permits the escape of gas, so that the pressure inside the tank does not increase to dangerous levels.

Section 11.1 Review Questions

(Student textbook page 506)

1. Attractive forces between particles are strongest in the solid state and weakest in the gas state.
2. A substance composed of highly polar molecules will have stronger attractive forces between the molecules than one with less polar molecules. The substance with stronger dipole–dipole interactions will remain in the liquid state at a higher temperature than will a substance that has weaker dipole–dipole interactions.
3. Diagrams should show that methanol is a polar molecule with extensive hydrogen bonding. The attractive forces (dipole–dipole and hydrogen bonding) contribute to it being a liquid at room temperature. Phosphine is a non-polar molecule with much weaker attractive forces. Therefore, it is a gas at room temperature.
4. Ammonia has a lower boiling point than water because its intermolecular forces are weaker than those of water.
5. Sample answer: solids and liquids have much lower incompressibilities, and their densities are much higher
6. Gases have a low viscosity and can fit easily through tiny holes. Helium atoms are very small and can fit through the “molecular mesh” of the balloon. As the helium leaks out of the balloon, the density changes and the balloon sinks to the ground.
7. **a.** gases have much lower viscosity than liquids
   b. gases are highly compressible and liquids are not
   c. gases have much lower densities than liquids
   d. all gases are miscible but some liquids are immiscible
8. Gases expand when heated. Therefore, in hot air ballooning, the air inside the balloon expands and its density is reduced. The air becomes less dense than the surrounding air and allows the balloon to become airborne.
9. Molecules of air are in constant random motion, and collide with each other and the walls of the inside of the basketball.
10. **a.** Gases are compressible, allowing for storage of larger amounts than by the volume of the tank. A barbecue propane tank compresses the gas into the liquid state, allowing for an increased volume of propane in the tank.
    b. Gases have very low resistance to flow and mix evenly with the surrounding air.
    c. Gases mix evenly and have low resistance to flow and can easily be blown throughout the surrounding air.
11. The hand pump pushes air into the tire, causing tire inflation. Because air is compressible, its molecules can be pushed closer together so that more air can be added. Because air has a low resistance to flow, it can be pushed through a small opening with relative ease. Because air mixes completely and evenly, it fills the tire completely, even though it is added at only one point.
12. Kinetic energy is not lost in an elastic collision. In an inelastic collision, some of the kinetic energy of the particles is lost in the form of heat.
13. Ideal gases are considered to consist of particles that are point masses (they have no volume), which do not exert attractive or repulsive forces on each other. Ideal gas particles also undergo elastic collisions. Real gases, however, are composed of particles that have volume, that do experience attractive and repulsive forces, and do undergo elastic collisions.

14. In a volleyball filled with many gas molecules, a gas molecule will travel in a straight line, changing direction when it collides with other gas molecules or the inner surface of the ball, as shown in diagram A. (If there were only one gas molecule in the entire volleyball, it would follow the path shown in C.)

15. a. Molecules of gas will move in straight lines between collisions, and some molecule-to-molecule collisions will put a molecule on a straight path until it strikes the side of the container. Higher temperature will cause particles to move more rapidly, resulting in higher collision frequency. So, eventually, the gas particles will fill the entire container.

b. There are relatively large spaces between gas particles and little repulsive forces acting on the particles. Therefore, the particles can easily be pushed closer together.

Section 11.2 Review Questions

(Student textbook page 515)

1. Torricelli used an apparatus that monitored the level of mercury in an otherwise empty tube, which was sitting in a dish of mercury. The surrounding atmospheric pressure pushing down on the mercury in the dish causes the level of mercury in the tube to rise to a certain level. The height that it reached depended on the amount of atmospheric pressure.

2. Atmospheric pressure decreases as altitude increases.

3. a. A drinking straw is used to move liquids upward, against gravity. The surrounding atmospheric pressure is pushing down on the fluid in the glass, forcing some fluid to rise up the straw, until the pressure exerted by the atmosphere on the fluid inside the straw is equal to the pressure exerted on the fluid in the glass (outside the straw).

b. A change in altitude will affect the amount of pressure exerted on the fluid in the glass, and therefore the height to which the fluid will rise in the straw. At a lower altitude, more pressure will be exerted on the fluid in the glass, causing the fluid to rise higher in the straw, and reducing the amount of suction needed to bring the fluid the rest of the way to the top of the straw. At a higher altitude, the opposite will be true. The atmospheric pressure will be lower, the fluid level in the straw will be lower, and the suction needed to move the liquid up will be greater. (The very slight change in gravity at different altitudes would have a negligible effect.)

4. At reduced atmospheric pressure there are fewer oxygen gas molecules available to breathe for a given volume, such as a lungful.

5. a. 1.25 atm **b.** 1.5 bar **c.** 105 kPa **d.** 1.25 atm

6. The student should take recordings of atmospheric pressure before and after the experiment. If the atmospheric pressure was considerably higher later in the day, it would cause a decrease in the volume of the hydrogen gas and, therefore, a decrease in the size of the balloon collecting it. The student could also collect room temperature data, to see if the temperature changes over the course of the day.

7. The volume of air trapped inside the marshmallow increases when the pressure in the flask decreases.

8. When a diver rises, the pressure due to the water above is reduced. When the pressure is reduced, the gas volume in the lungs expands and could cause internal damage if the diver attempts to hold his/her breath.

9. Boyle used a “J” tube sealed at the top of the short arm. Using liquid mercury, he trapped a small amount of gas in the J tube. As the height of mercury was increased in the long arm of the J tube, increasing the pressure on the trapped air, the volume of the air decreased.

10. a. Yes, it shows an inverse relationship between volume and pressure and the change is proportional (i.e., one doubles and the other is halved).

11. 3.0 L

12. 4.17×10^2 kPa

13. 1000

14. Since the pressure has tripled, the volume will be reduced to one-third the original volume, or 1 L. Diagrams should reflect what is represented in Figure 11.12 on page 514. When the external pressure on a gas increases, the volume available for the gas molecules decreases. The molecules are now closer together and collide with each other and the walls of the container more frequently. This causes the force exerted by the molecules to increase, which results in an increase in the pressure of the gas.

Section 11.3 Review Questions

(Student textbook page 527)

1. Atoms/molecules of a real gas take up space; therefore, they must have volume. Atoms/molecules of an ideal gas have zero volume.

2. Similarities: both are temperature scales; the sizes of the units are the same Differences: the units are different (°C and K); the starting points of the scales are different (0 K is –273°C)
3. **a.** 311 K **b.** 395.6 K **c.** 233 K **d.** 1.85°C **e.** –99.55°C **f.** 6.00×10^2°C
4. The volume decreases as the temperature decreases; referred to as Charles's law.
5. Graphs should be similar to any of the line graphs in Figure 11.15B. Plotting volume versus temperature (in K), the graphs should show a directly proportional relationship between volume and temperature of a gas.
6. Sample answer: When a balloon filled with air is exposed to higher temperatures it may burst from expanded volume of the air.
7. The law is based on a direct proportion between volume and temperature. This relationship only exists with temperatures measured in units of kelvins, so temperature units in problem calculations must be in Kelvin.
8. 0.7 L
9. doubling of the temperature, to 60°C
10. Graphs should be straight lines of pressure (y-axis) versus temperature in kelvin units (x-axis), showing a directly proportional relationship (e.g., doubling one causes the other to double). The data does support Gay-Lussac's law.
11. 75.4 kPa
12. 6.5×10^3 kPa
13. 17.4 psi
14. Sample answer: The container must be made of material that can withstand high pressures, must not react with gases, it must have a device that delivers gas at a reasonable pressure (e.g., some type of valve), and it should have a safety valve that would releases excess pressure if it builds up due to high temperatures.

Practice Problems

(Student textbook page 514)

1. 2.29 atm
2. 3.98×10^2 kPa
3. 24 atm
4. 0.27 L
5. 1.3×10^2 kPa
6. 4.4×10^2 L
7. 14.3 mL
8. 1.1×10^2 L
9. 1.73×10^3 L
10. **a.** 3.6×10^3 L **b.** 5.6×10^2 min

(Student textbook page 522)

11. 11 L
12. 35.5 mL
13. 2.14 L
14. 95 L
15. 561 cm^3
16. 539 K
17. 308 K
18. 27°C
19. it is 1.25 times room temperature
20. –214°C

(Student textbook page 525)

21. 42.0 kPa
22. 327 kPa
23. 2.8×10^3 kPa
24. 4.3×10^2 kPa
25. **a.** 7.2×10^2 kPa **b.** about 7 times higher
26. 1.1 atm
27. 136 K
28. 1.5×10^2
29. 273°C
30. 273°C

Chapter 11 Review Questions

(Student textbook pages 533–5)

1. c
2. d
3. d
4. b
5. c
6. b
7. e
8. e

9.

Particles in States of Matter

Property	Solid	Liquid	Gas
Position of particles in relation to one another	Highly organized and closer together than particles in gas or (usually) liquid state	Less organized and (usually) further apart than particles in solid state, but closer together and more organized than particles in gas state	Little organization of particles and further apart than particles in solid and liquid states
Strength of attraction between particles	Strong	Intermediate between solid and gas	Weak
Type of motion of particles	Most have only vibrational motion	Vibrational and rotational, and in some cases translational	Vibrational, rotational, and translational

10. There is more space between particles in the gas state, than in either the liquid or solid state. Therefore, it is easier to compress or push together the particles in the gas state.

11. Water molecules are polar molecules; therefore, dipole-dipole interactions occur, such as hydrogen bonding. Carbon tetrachloride is a non-polar molecule; therefore, weaker attractive forces exist, due to temporary dipole formation.

12. An elastic collision is one in which particles do not lose kinetic energy. The kinetic molecular theory of gases assumes that collisions of gas particles are elastic collisions.

13. a. 551 kPa **b.** pumping: 0.16 atm; resting 0.11 atm **c.** 80 kPa **d.** 1520 mmHg

14. When temperature decreases, the speed of the gas molecules decreases. The molecules, therefore, collide with the walls of the balloon less frequently, decreasing the pressure. When the external pressure remains the same, the volume of the balloon decreases until the pressure of the gas and the pressure of the atmosphere is equal.

15. 214 kPa

16. 0.16 L

17. Increasing the Kelvin temperature of a gas by a factor of four will cause the volume of the gas to increase by a factor four, assuming all other variables remain constant.

18. a. 298 K **b.** 263.2 K **c.** 4°C **d.** −108°C

19. −25°C

20. a. There is a decrease in volume, while same amount of molecules is present in the bottle. This causes an increase in pressure.

b. 303 kPa

21. a. Gay-Lussac's law is being investigated, since the changes in pressure and temperature (in K) of a gas are being monitored.

b. Yes the gas law is verified because there is a directly proportional relationship between pressure and temperature (in K); for example, if the temperature is doubled, the pressure is doubled.

22. 923°C

23. Presentations should include a discussion of one of the three laws studied in the chapter: Boyle's law, Charles's law, or Gay-Lussac's law.

a. Indications of the molecular activities based on the kinetic molecular theory should be based on information provided on student textbook pages 514 and 522.

b. The mathematical equations for each law are:

Boyle's law: $P_1V_1 = P_2V_2$

Charles's law: $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

Gay-Lussac's law: $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

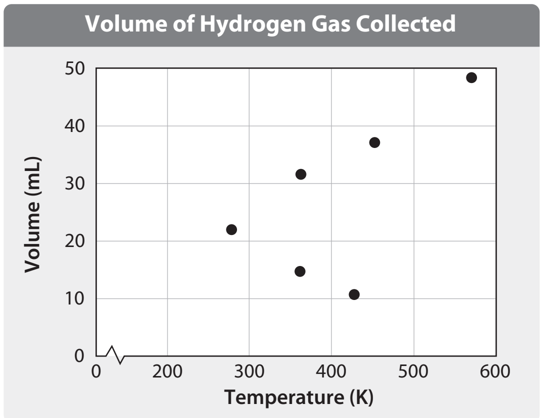
c. Sample answers: Boyle's law applications include scuba diving and the use of a syringe (when the volume of a gas increases, the pressure of the gas decreases, at constant amount and temperature of the gas). Charles's law application includes hot-air ballooning and how a gas-filled flexible container can increase or decrease in size with change in temperature of the gas (when the temperature of a gas increases, the volume of the gas increases, at constant pressure and amount of gas). Gay-Lussac's law applications include a change in air pressure of a tire when the temperature changes, and storage of compressed gases in gas cylinders. This is why warnings are printed on aerosol cans—heating the container can increase the pressure to the point that the container explodes.

d. Answers may include information provided on pages 511, 512, 516–9, and 523-4 of the student textbook.

24. a. Charles's law is being studied.

b. 32 mL; −93 °C

c.



d. Answers should be close to 0 K, which is absolute zero. If graphs have been done using Celsius degrees, the value should be close to −273.15°C

25. a. Once the two pressures are the same, no more aerosol material is released. The release of any material from such cans is based on differences in pressure; when the pressure in the can is higher than atmospheric pressure, material will be expelled from the can.

b. An aerosol can has a fixed volume. If the temperature of the contents is increased when placed in a fire, the pressure of the gas inside will also increase. This will occur, until the container can no longer withstand the force on the walls from the gas molecules, and the can will explode (increase in volume).

c. Web pages should contain the information provided in parts **a** and **b**, and be prepared in a manner that is engaging and written at an appropriate level for the general public

26. Assessment BLM A-13 Concept Map Checklist can assist students in creating the organizer and provides a framework for assessment.

27. a. 59°C **b.** 170 cm^3

28. The amount of oxygen in the blood depends on the amount of oxygen available in the air we breathe, as well as how many red blood cells are available to bind the oxygen. There are fewer oxygen molecules available, for a given area, at higher altitudes. Having a higher number of red blood cells that oxygen molecules can bind allows for higher amounts of oxygen to be present in the blood, than if fewer red blood cells were available. Since more oxygen molecules, for a given area, are available at lower altitudes individuals do not need to have as many red blood cells.

29. a. The range of pressures is given is the range needed in order for the tire to remain intact; too high a pressure will cause the tire to explode. A lower pressure might be used to recognize that the pressure may increase due to squashing of the tire on bumps, or because the tire heats up as it flexes in use. See answer (b) also.

b. The weight of someone sitting on the bike will cause an increase in the external pressure on the tire, due to the force acting on the tire.

c. 1.82×10^3 cm^3; the volume changes by a factor of 1.52.

d. No, they would not; an increase in temperature of the air in the tire causes increases in volume and pressure of the air.

30. As the pressure of the water vapour increases, so does the temperature of the vapour.

31. a. As a gas, methane is compressible, has low viscosity, it mixes evenly and completely, has low density, and expands with an increase in temperature. Methane is a non-polar molecule, so the only attractive forces are weak ones due to temporary dipole formation.

b. At room temperature methane is a gas, while water is a liquid and sodium chloride is a solid. Therefore, particles of methane have vibrational, rotational, and translational motion, while water has only vibrational and rotational, and sodium chloride only has vibrational.

c. The volume of methane gas will increase with an increase in temperature or a decrease in pressure and decrease with a decrease in temperature or an increase in pressure.

d. Methane clathrates are a form of ice that contains large amounts of methane. Scientists have hypothesized that rises in sea temperature could cause a release of this methane gas. Since methane is a greenhouse gas, this could then further contribute to global warming and result in a runaway climate change effect and possible extinction.

Chapter 11 Self-Assessment Questions

(Student textbook pages 536–7)

1. b

2. a

3. e

4. a

5. a

6. a

7. b

8. a

9. b

10. c

11. The graphic organizer should summarize differences in viscosity, compressibility, and density. Gases are highly compressible, have very low viscosity, and very low densities. Liquids are not easily compressible, have higher viscosity and density. Similarities include that both gaseous and liquid particles have vibrational and rotational motions and some liquids also have the translational motion that gas particles have.

12. a. Gases are miscible and become evenly distributed in a container because they are in constant motion.

b. Gases are much less dense than liquids.

13. The kinetic molecular theory of gases is a model that is used to explain the behaviour of gases. It is based on assumptions about the behavior of an ideal gas. The assumptions are that particles are in constant, random motion with high translational kinetic energy, that particles have no volume, that particles do not experience any attractive or repulsive forces, that particles only undergo elastic collisions, the collisions are with other molecules and with the vessel wall, and between collisions particles move in straight lines, and the average kinetic energy of the particles is directly related to temperature.

14. As the air in the jar cools, the particles move more slowly and come closer together. They exert less pressure internally on the sides of the jar. The air pressure is then higher outside the jar than inside, and the metal lid is pushed inward by the external air pressure.

15. a. Atmospheric pressure is the force that a column of air exerts on Earth's surface; it is a measure of the current air pressure and can fluctuate from day to day. Standard atmospheric pressure is a reference point with a defined value—760 mHg; the atmospheric pressure in dry air at a temperature of 0°C and at sea level.

b. The term refers to the height of mercury in a column that counterbalances the pressure exerted by the atmosphere.

16. a. 79.9 psi

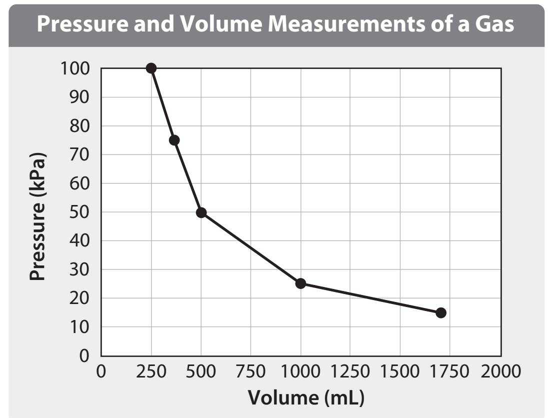
b. 310 mmHg

c. 53 kPa

d. 677 mmHg; 90.2 kPa

17. a. $x = 1.7 \times 10^3$ mL

b.



18. 100 kPa

19. Perform a series of experiments studying changes in volume of a gas at constant pressure with change in temperature (Celsius) and plot the data. Extrapolating back to zero volume, will yield the value for absolute zero in terms of degrees Celsius. Alternatively, study changes in pressure at constant volume with change in temperature, then plot pressure versus temperature and extrapolate back to zero pressure, to get the same thing.

20. Similarities: they both measure temperature, there are 273 temperature units between absolute zero and the freezing temperature of water and 100 temperature units between freezing and boiling temperatures on both scales; the sizes of the temperature units are the same. Differences: the Celsius scale used degrees, while the Kelvin scale uses kelvins, the starting points of the two scales differs, there are no negative values on the Kelvin scale, but is on the Celsius scale.

21. 2.1×10^2 mL

22. 3.1 L

23. 40 000 kPa

24. 11.7 psi

25. Boyle's law (volume decreases/increases with increase/decrease in pressure—lying on an air mattress and it becomes thinner; Charles's law (volume increases/decreases with increase/decrease in temperature—a tire looks flat when it is cold out; Gay-Lussac's law increase/decrease in temperature causes an increase/decrease in pressure. Pressure in a tire increases as the tire heats up with use (because flexing of the rubber causes it to heat up).

Chapter 12 Exploring the Gas Laws

Learning Check Questions

(Student textbook page 545)

1. Boyle's and Charles's laws
2. Volumes of gaseous reactants and products are always in whole-number ratios, when measured at the same temperature and pressure.
3. 586 mL
4. The ratio of the volumes is the same as the ratios of the coefficients of the balanced equation.
5. a. Under the same temperature and pressure of a reaction, volumes of gaseous reactants and products are always in whole-number ratios. When measured under the same conditions, the volumes of butane, oxygen, carbon dioxide, and water will be in a 1:6:4:4 ratio. The balanced chemical equation for the combustion of butene gas, $C_4H_8(g)$ is:
   $C_4H_8(g) + 6O2(g) \rightarrow 4CO_2(g) + 4H_2O(g)$
   b. 62 mL
6. 15 L

(Student textbook page 557)

7. combined gas law and Avogadro's law
8. For the universal gas constant value of 8.31 kPa × L/mol × K, the units to use are: pressure in kPa, temperature in K, and volume in L, to match the units used for the Universal Gas Constant.
9. 280 kPa
10. helium: 0.24 atm; argon: 0.50 atm; neon: 1.3 atm
11. Humidity represents water vapour in the air, which contributes its own partial pressure to the total pressure.
12. 81.1 kPa

(Student textbook page 566)

13. In the homosphere layer the gases are evenly mixed and behave like an ideal gas. In the heterosphere the gases are layered and more limited and include charged ionic gases.
14. The main gases present are nitrogen, oxygen, argon and carbon dioxide.
15. Criteria air contaminants are those pollutant gases that are considered to have the greatest impact on air quality and human health.
16. Convection occurs in the homosphere due to heating of the land by radiant energy. As gases heat up at ground level, they get less dense and rise upwards while the colder, denser gases sink downwards.
17. AQHI stands for Air Quality Health Index. It is a scale used to indicate air quality and associated health risks.
18. Air quality in Ontario would reach levels over 7 when temperatures are high and air is not mixing. This would occur mostly in summer and during periods of heavy traffic and industrial emissions.

Caption Questions

Figure 12.5 (Student textbook page 557): The pressure would be 2.0 atm instead of 1.5 atm.

Figure 12.6 (Student textbook page 558): If any air were already in the cylinder before the gas was collected, the measured volume of the collected gas would be incorrect.

Figure 12.9 (Student textbook page 562): Gay-Lussac's law; could be placed connecting to the combined gas law

Figure 12.10 (Student textbook page 564): For the troposphere, temperature is primarily due to transfer of heat from Earth's surface. The temperature decreases as the distance from Earth's surface increases. Ozone in the stratosphere absorbs energy from the sun, and more energy is absorbed with increased altitude. This causes an increase in temperature in this layer. The lack of ozone in the mesosphere causes a decrease in temperature. The increase in temperature in higher layers is due to absorption of energy from the sun by gases.

Section 12.1 Review Questions

(Student textbook page 550)

1. You would need the temperature and the pressure, according to the combined gas law.
2. a. increase; the decrease in pressure has a greater impact on volume change than the decrease in temperature. The pressure decreases by half (from 2 atm to 1 atm), while the temperature increases by less than half (473.15 K to 373.15 K).
   b. decrease; the increase in pressure has a greater impact on volume change than the increase in temperature (given in kelvins), since the pressure increases by four times (from 1 atm to 4 atm), while the temperature decreases by less than two times (from 373.15 K to 273.15 K).
   c. decrease; both temperature decrease and pressure increase result in decreased volume

3. It is important to be able to predict how large in volume a weather balloon becomes at specified altitudes. Since the combined gas law considers temperature, pressure, and volume, the volume of a weather balloon can be controlled if you know the temperature and pressure at the specified altitude.
4. 84°C
5. 74.8 kPa
6. 4×10^3 h
7. Avogadro's law states that equal volumes of gases at the same temperature and pressure contain the same number of molecules. The volume of a gas is directly proportional to the number of molecules of the gas, when the pressure and temperature are constant. One mol of any substance represents 6.02×10^{23} molecules. Both gases occupy 29 L, since there is 1 mol of each gas at the same temperature and pressure..
8. 30 L
9. 7.0×10^2 mL
10. At the same temperature and pressure, equal volumes of gases contain the same number of molecules of the gases.
11. 0.14 mol
12. **a.** 0.446 mol **c.** 2.69×10^{23} molecules
b. 17.8 g **d.** 22.4 L/mol
13. Graphic organizers should show that the acronyms stand for standard temperature and pressure (STP) and standard ambient temperature and pressure (SATP). Both are standards set by chemists for reporting gas volumes at specified conditions. They differ in the conditions specified. STP is 273.15 K and 101.325 kPa, and SATP is 298.15 K and 100 kPa. Since gas volume is affected by temperature and pressure, use of these allows scientists to communicate information about gas volumes at specified conditions
14. 42.9 L/mol

Section 12.2 Review Questions

(Student textbook page 563)

1. Graphic organizers should indicate that the combined gas law and Avogadro's law are used to derive the ideal gas law, and show how the combined gas law is derived from Boyle's Law and Charles's Law. Using the ideal gas law, one side of the equation is set to standard conditions. Under standard conditions, 1 mole of gas occupies 22.4 L at 101.3 kPa and 273 K. When calculated this gives a constant value called R, the ideal gas law constant. The ideal gas law is valuable because it allows for predictions of volume, temperature, pressure, or gas quantity given 3 of the other variables.
2. **a.** $V = \frac{nRT}{P}$ **b.** $P = \frac{nRT}{V}$ **c.** $T = \frac{PV}{nR}$ **d.** $n = \frac{PV}{RT}$
3. 8.6×10^3 L
4. 8.23×10^{-3} kPa
5. 90.2 g/mol
6. 38.1 g/mol; fluorine gas
7. 1.2 g/L
8. C_2H_2
9. 97.5 kPa
10. When two gases are added together, and the volume and pressure remain constant, the total pressure of the mixture is the sum of the pressure of each gas (or partial pressures).
11. 107 g
12. 8.59 L
13. 3.2 L
14. Real gases deviate from ideal gases at low temperatures and high pressures. As pressure increases, molecules are pushed closer together, increasing the intermolecular attractive forces. These forces reduce the ability of molecules to strike the surface of the container, hence the pressure is lower than it should be for an ideal gas. At low temperature, with lower speeds and reduced kinetic energy, molecules cannot readily break their attractive interactions. Eventually these attractive interactions cause the gas to condense into a liquid. Also, when the overall volume of a real gas is reduced by high pressure or low temperature, the real volume of the molecules, which is assumed to be zero for an ideal gas, becomes a significant part of the overall volume. Diagrams should be based on Figures 12.7 and 12.8 on pages 561–2 of the student textbook.

Section 12.3 Review Questions

(Student textbook page 569)

1. Similarities: both are regions of Earth's atmosphere, both are composed of gases. Differences: composed of different gases, homosphere has a uniform composition while mixing of gases in heterosphere does not occur; homosphere is lower in altitude than the heterosphere.

2. Air pollutants that have been identified by the federal government as having an effect on human health; carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, and particulate materials.
3. The Air Quality Health Index was developed to help assess potential effects of air quality and to provide health messages. Air quality management is mainly the responsibility of the provincial and territorial governments and is overseen by the federal government through the Canadian Environmental Protection Act, 1999.
4. Because the governments must provide cities, towns, companies, industries, and other agencies that are affected enough time to implement any changes to meet those target goals
5. **a.** transportation **b.** oil and gas industries
   c. home firewood burning
6. approximately 17%
7. it contributes about 10% to VOCs but a negligible amount to NO*x*
8. oil and gas and forms of transportation contribute the most; recommendations should therefore focus on changes related to these industries (e.g., finding and using alternative fuel sources, increasing public transportation)
9. possible recommendations: reduction in transportation, or alternative transportation options, and reducing burning of firewood in homes
10. In general, both systems monitor similar pollutants that are considered to be harmful to human health. A key difference is that the AQI assesses risk based on the highest level of one of the monitored pollutants, whereas the AQHI assesses risk based on a combination of monitored pollutants. Direct students to websites for provincial Ministries of the Environment, as well as Health Canada and Environment Canada, to research and evaluate the pros and cons of each system. Many students may consider the AQHI to be superior to the AQI, since it deals with more than a single pollutant. However, the two systems serve different purposes (the AQI being integral to Ontario's issuing of smog alerts).
11. The troposphere, stratosphere, and mesosphere are identified according to pressure and temperature differences. They are part of the homosphere, which contains a uniform blending of 78% nitrogen, 21% oxygen, and other remaining components, such as water vapour, and carbon dioxide. The thermosphere and exosphere compose the heterosphere, which contains ions of oxygen and oxygen-containing compounds, as well as ions of nitrogen and nitrogen-containing compounds.
12. The six criteria air contaminants identified by the EPA are: ozone, particulate matter, carbon monoxide, nitrogen oxides, lead, and sulfur dioxide. The criteria air contaminants identified by Canada are carbon monoxide, nitrogen oxides, sulfur dioxide, VOCs, and particulate materials. Differences are due to the fact that the EPA identifies those that can harm the environment and cause property damage, in addition to harming human health.
13. Accept all reasonable answers, ensuring that students have provided evidence to support their opinions. Many students may argue that it does not surprise them since these gases do not directly affect human health.
14. Presentations should include the contribution of SO*x* and NO*x* compounds to acid precipitation.

Quirks and Quarks: PFOA—Here Today, Here Forever? Questions

(Student textbook page 568)

1. Key issues include: it does not break down easily so stays in the environment for a long time; it is potentially toxic and carcinogenic; it bioaccumulates in the food chain; and it travels through the atmosphere, ending up far from its source.
2. Answers should be based on current information from Health Canada and Environment Canada.
3. Environmental chemists examine the ways in which chemicals and the environment interact. They can work in a wide variety of industries, such as mining, forestry, the petroleum or gas industry, pharmaceutical manufacturing, waste management, utilities (e.g., power generation), or as independent consultants. Many work for government at national, provincial, or local levels in the departments of environment, health, or parks and recreation. Others may work with ministries of natural resources, or for conservation organizations, such as Ducks Unlimited. Environmental chemists might identify natural resources, or work in environmental preservation or remediation, designing methods to avoid or clean up pollution. They may also investigate environmental patterns and changes, and design or monitor environmental policies.

Practice Problems

(Student textbook page 542)

1. 620°C
2. 13.6 mL
3. 0.214 mL
4. 22°C
5. 104 kPa
6. 1.2 atm
7. 21 mL
8. 57°C
9. 3.7×10^3 cm^3
10. 6×10^3 m^3

(Student textbook page 549)

11. 5.9 g
12. 12 L
13. 17.7 L
14. 1.69 L
15. 141 L
16. 8.59 g; 3.03×10^{23} molecules
17. 26 L/mol
18. 25.9 L/mol
19. **a.** 1.46×10^{-3} mol **b.** 1.46×10^{-3} mol
    c. 24.5 L/mol
20. 22.3 L/mol

(Student textbook page 556)

21. 1.4×10^2 L
22. 1.1×10^4 L
23. 166°C
24. 118 kPa
25. 160 g
26. 6.0×10^1 g/mol
27. 83.8 g/mol; gas is most likely krypton
28. 1.775 g/L
29. **a.** C_2H_5 **b.** 58 g/mol **c.** C_4H_{10}
30. C_8H_{18}

(Student textbook page 560)

31. 0.036 L
32. 16 L
33. 69 L
34. 533 L
35. 15.6 L
36. 0.787 L
37. 2.73×10^{-3}g
38. 0.32 g
39. 0.16 g
40. 0.16 L

Chapter 12 Review Questions

(Student textbook pages 577–9)

1. a
2. c
3. b
4. b
5. e
6. c
7. a
8. d
9. the volume occupied by 1 mol of a gas
10. Answers should show that they need the mass of the gas, the pressure, the temperature and the volume and to use the ideal gas law.
11. 127 L
12. 4900 kPa
13. 900 kPa
14. 2.75 g
15. 1.0×10^2 kPa
16. **a.** The pressure in the tank has been reduced to the same pressure as atmospheric pressure. When there is no longer a difference in pressures, gas will no longer be released form the cylinder.
    b. 1 mol **c.** 30 g
17. **a.** 140 g/mol **b.** 120 g/mol
18. 20.2 g/mol; neon
19. $C_4H_{12}O_2$
20. 1.4 g/L
21. 97.5 kPa
22. **a.** $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$
    b. 2.5×10^3 L **c.** 2.0×10^3 L
    d. 3.0×10^3 L **e.** 5.0×10^3 L
23. **a.** $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
    b. 1 L **c.** 3 L **d.** 4 L

24. a. $NH_4NO_2(s) \rightarrow N_2(g) + 2H_2O(g)$

b. 4.7×10^{-3} mol

25. 69 L

26. 0.25 g Mg; 6.7 mL HCl

27. a. Diagrams should show space-filling models in the same format as the diagram provided in the question. Answers should also include the following chemical equation, in the same manner as provided in the question: $3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$.

b. Diagrams should show space-filling models in the same format as the diagram provided in the question. Answers should also include the following chemical equation, in the same manner as provided in the question:
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$.

28. Diagrams should show that the sum of the partial pressures of each gas is the total pressure of the combined mixture of gases, when volume and temperature are constant.

29. a. 1992–2000

b. 2000–1, 2004–6 and 2007–8.

c. new guidelines for stricter emission controls; technical improvements in combustion technology

d. Answers should include some analysis of the data. Opinions will likely depend on what time periods they focus on. For example, some students may argue that yes it has helped because there are fluctuations that are more gradual than the steady increase seen between 1992 and 2000.

30. Assessment Checklist A-13: Concept Map can assist students with creating the organizer.

31. a. Answers should reflect an awareness that growing food, manufacturing and running electronics and appliances, and using motor vehicles require an input of energy generated by an energy resource that—depending on location (provincially or internationally)—likely involves the release of greenhouse gases resulting from the burning of fossil fuels.

b. Any actions that do not exploit greenhouse-gas-producing resources—for example, walking, riding a bicycle, using solar-cell technologies in combination with rechargeable batteries, establishing a backyard, balcony, or community garden—are acceptable.

32. Examples of industrial factors include the presence (and types) of manufacturing facilities or power plants. Examples of geographic factors include terrain, the presence or absence of bodies of water, and how urban or rural an area is. Examples of meteorological factors include patterns of precipitation and wind. A suitable answer will simply list examples. A stronger answer will attempt to describe and infer linkages among these factors, demonstrating an appreciation that many contributing factors—some of which are not directly subject to human activities and technology—interact to affect air quality

33. Locations for which AQHI data are available may be accessed from Environment Canada website. The search string "local aqhi conditions" also provides results in a web browser. Inferences should take into account factors such as territorial and local geography, types of economic activity, population size, and urbanization.

34. a. 2.2×10^6 g **b.** 7.1×10^6 g

Chapter 12 Self-Assessment Questions

(Student textbook pages 580–1)

1. c

2. a

3. e

4. d

5. d

6. e

7. c

8. e

9. d

10. b

11. There is an eightfold increase in the volume of the gas.

12. 20 m^3

13. Gases of equal temperature and pressure, and having the same volume, will contain the same number of atoms, according to Avogadro's Law. Since the cylinders have the same volume, temperature and number of molecules, they must have the same pressure.

14. 24.4 L/mole

15. a. 1.1×10^6 g **b.** 8.9×10^5 L

16. Instructions should be based on the steps in the sample problem on page 555. Sample answer:
Using the ideal gas law and substituting in the values for temperature (in K) and pressure, solve for the number of moles (n) in 1.00 L of gas.

$T = 15°C + 273.15 = 288.15$ K

$n = \frac{PV}{RT}$

For the example given:

$n = 0.04262$

Using the molar mass of radon (222 g/mol), determine the mass of the radon

$m = n \times M$

$m = 0.04262 \cancel{\text{mol}} \times 222 \frac{\text{g}}{\cancel{\text{mol}}}$

$m = 9.4616$ g

Then substitute the value for the mass of 1.00 L of radon gas into the formula for density,

$$D = \frac{m}{V}$$
$$= \frac{9.4616 \text{ g}}{1.00 \text{ L}}$$
$$= 9.5 \text{ g/L}$$

17. molar mass 2.0 g/mol; H_2

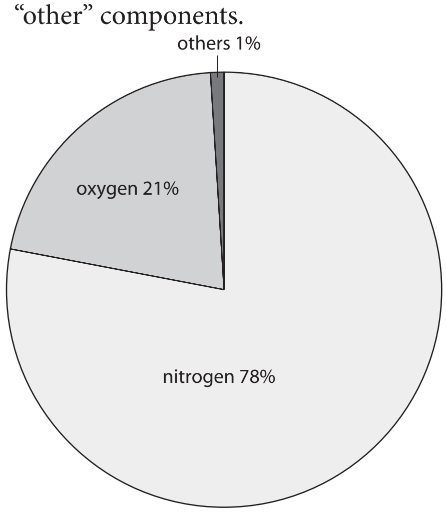
18. 30.5 kPa

19. When a gas is collected over water, water vapour contributes to the total pressure. This must be compensated for by subtracting the vapour pressure of water at a given temperature from the total pressure.

20. $2N_2(g) + O_2(g) \rightarrow 2N_2O(g)$; volume of $N_2(g)$: 34 L; volume of $O_2(g)$: 17 L

21. 6.0×10^3 g

22. Pie graphs should be similar to the one shown here; they may provide examples of others, from Table 12.5 on page 565 of the student textbook. Some students may try to provide too much detail by attempting to incorporate all of the information, so guidance could be provided regarding how to best represent the "other" components.



23. Answer should include a basic definition of AQHI, that it is used for indicating the quality of air we are breathing at a certain period of time, and how this helps determine potential human health risks.

24. Graphic organizers should include the criteria air contaminants (carbon monoxide, nitrogen oxides, sulfur dioxide, volatile organic compounds, and particulate materials) and examples of at least three of their sources, taken from Figure 12.11 on page 565 of the student textbook.

25. a. The conditions of any given vehicle motor and transmission system differ while the vehicle is idling and while it is in motion.

b. Students should readily appreciate and communicate that any activities that maintain a vehicle in optimum operating condition will contribute toward "clean driving." Any reasonable suggestions that respect this idea should be accepted.

Unit 5 Review Questions

(Student textbook pages 585–9)

1. b

2. e

3. e

4. b

5. e

6. c

7. e

8. b

9. b

10. d

11. In a mercury barometer, liquid mercury is placed in a tube connected to a reservoir of mercury exposed to the atmosphere. As the atmospheric pressure changes, the level of mercury in the barometer also changes (the standard atmospheric pressure being 760 mmHg). If water was used instead, the height of the barometer would be much larger as water is much less dense than liquid mercury, since a longer column of water is required to create a pressure equal to atmospheric at the bottom.

12. a. Pressure would decrease as the volume for the gas increases. There would be fewer gas molecules striking a given surface of the container.

b. Since density is mass per unit volume, as the volume increases and the moles of gas remain the same, the density will decrease.

13. a. Charles's Law; molecules move faster and further apart as temperature is raised, which results in increasing the volume

b. Gay-Lussac's Law; molecules move slower and have decreased kinetic energy as temperature is lowered, striking the surface of the container less frequently and causing a reduction in pressure.

c. Avogadro's Law. Increasing the moles of a gas increases the pressure because more molecules strike the surface of the container.

d. Boyle's Law, increased external pressure causes the molecules to move closer together, reducing the volume.

14. Change in temperature and pressure affects volumes of all gases equally.

15. Is the volume occupied by 1 mole of a gaseous substance? The ideal gas law is derived based on the average value of 1 mole occupying a volume of 22.4 L at STP.

16. nitrogen, 78%; oxygen, 21%; minor constituents, 1%. Table 12.5 includes a list of minor constituents.

17. The Air Quality Health Index is a system that describes the relative air quality in a Canadian city on a given day. Poor air quality can affect the health of individuals, particularly those who are elderly, young, or have a health condition. Individuals can be advised under poor air quality to take proper precautions under such conditions.

18. Pressure Unit Conversions

Pressure (kPa)	Pressure (mmHg)	Pressure (atm)	Pressure (psi)
102	765	1.01	14.8
3.0×10^2	2300	3.0	44
2.76×10^2	2.07×10^3	2.72	40.0

19. Air is being compressed; air is unable to escape to displace liquid, once the bottom of the funnel is covered by water. So, pressure builds up in flask resisting further pouring of fluids.

20. 617 cm^3

21. a. 12 psi

b. Increasing temperature causes an increase in pressure. This causes an increase in bounce due to increased firmness of the ball.

22. 22 atm

23. −18 °C

24. a. 2.8 g/L **b.** 0.50 g/L **c.** 0.635 g/L

25. 1.2 L/mol

26. 1.8×10^4 kg

27. 1.3×10^4 kPa

28. a. 0.011 mol **b.** 0.50 g **c.** 6.8×10^{21}

29. molar mass is 38 g/mol; identity is F_2

30. a. 98 kPa **c.** 4.3×10^{-3} mol

b. 4.3×10^{-3} mol **d.** 84 g/mol

e. *X* is magnesium. The carbonate formula is $MgCO_3$.

31. a. empirical formula: C_1H_1

b. molar mass: 78 g/mol

c. molecular formula: C_6H_6

32. a. $3CO(g) + 7H_2(g) \rightarrow C_3H_8(g) + 3H_2O(g)$

b. 1.050×10^3 L **c.** 466.7 L **d.** 38.6 L

33. mass of $CaCO_3(s)$ in tablet: 0. 40 g; 81% (m/m)

34. 180 L

35. a. Ammonium nitrate produces 310 L of nitrous oxide gas, while ammonia produces 730L. The volume of nitrous oxide produced from ammonia is over twice that produced by the same mass of ammonium nitrate.

b. 2500 L $N_2O(g)$, 7500 L $H_2O(s)$ **c.** 4.8×10^5 g

36. a. 2.7×10^4 L **c.** 3.6×10^4 L

b. 1.2×10^4 L **d.** 7.5×10^4 L

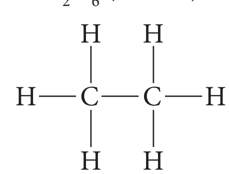
e. It produces only gases as products, and those in large quantities that can be used to propel the rocket.

37. a. lithium hydride reaction: $LiH(s) + H_2O(\ell) \rightarrow LiOH(aq) + H_2(g)$; magnesium hydride reaction: $MgH_2(s) + 2H_2O(\ell) \rightarrow Mg(OH)_2(aq) + 2H_2(g)$

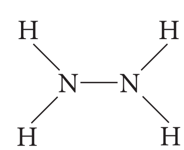
b. 33 g LiH(s), 54 g $MgH_2(s)$

38. a.

C_2H_6 (ethane)



N_2H_4 (hydrazine)



b. Since N–H bonds are more polar than C–H bonds there will be more intermolecular hydrogen bonding between molecules of N_2H_4 than between molecules of C_2H_6.

c. C_2H_6 has much weaker attractive forces between molecules and so is more likely to be a gas.

39. a. Diagrams should show that an increasing pressure forces the molecules to come closer together where intermolecular forces of attractive become strong enough and the distance between molecules small enough that a change in state occurs.

b. When going from a liquid to a gas, heat (energy) is required and this causes a resulting reduction in temperature.

40. a. Diagrams should indicate that the gas molecules will transfer from the left side to the right side, until an equal number exist on both sides of the divider.

b. increasing the temperature will cause the process to occur more quickly since the molecules will have higher kinetic energy and move faster.

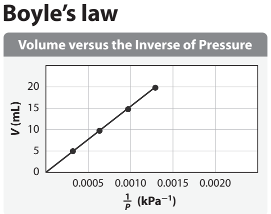
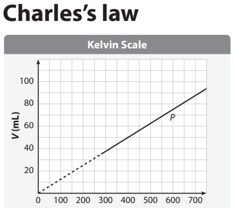
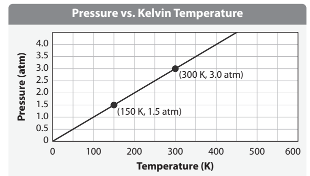
c. The density will decrease on the left-hand side of the partition and increase on the right-hand side of the partition, until equal numbers of molecules exist on both sides. Then, the densities will be the same on both sides.

41. Diagrams should show pressure differences between inside and outside the tire and the escaping of gas molecules due to differences in pressure and molecular motion.

42. Discussion of the three properties should include the units for each value, as well as the formulas used to calculate each value, as provided in Table 12.3 on page 552 of the student textbook.

43. The total pressure of the gas mixture in the cylinder on the far right is the sum of the pressures of the individual gases that are combined to form the mixture. Within the gas mixture, the pressure exerted by each individual gas is called its *Partial Pressure*.

44. Answers should include at least the following information, in a format of their choice.

<table>
<tr><th>Graph Appearance</th><th>Mathematical Equation</th><th>Constant Variable</th></tr>
<tr><td>Boyle's law

</td><td>$P_1V_1 = P_2V_2$;</td><td>amount and temperature of gas</td></tr>
<tr><td>Charles's law

</td><td>$V_1/T_1 = V_2/T_2$;</td><td>amount and pressure of gas</td></tr>
<tr><td>Gay-Lussac's law

</td><td>$P_1/T_1 = P_2/T_2$</td><td>amount and volume of gas</td></tr>
<tr><td>Combined Gas law</td><td>$V_1P_1/T_1 = V_2P_2/T_2$</td><td>amount and gas</td></tr>
<tr><td>Ideal Gas Law</td><td>$PV = nRT$</td><td></td></tr>
</table>

45. An ideal gas is composed of particles in continuous rapid motion that neither attract nor repel each other. Ideal gas particles occupy no volume. Real gas molecules occupy volume and may attract or repel each other. Cooling a real gas can slow their motions so that attractive forces can cause them to condense. At high pressure and low temperatures the attractive forces of real gases affect the volume and pressure. At high temperature and low pressure, the attractive forces are small enough, that real gases behave as ideal gases.

46. Removal of air creates a lower pressure inside the device. Atmospheric pressure pushing on the outside causes the two hemispheres to "stick" together. They could be released if the seal is broken and the vacuum is released.

47. At higher elevations, the boiling point of water is reduced due to lower atmospheric pressure. It will take longer to cook an egg because the water temperature is lower.

48. Conventional airplanes fly at very high altitudes where atmospheric pressure is very low and the partial pressure of oxygen gas is low. The air masks are necessary to provide oxygen if there is a loss of cabin pressure. The plane must decrease altitude to a point that the partial pressure of oxygen is high enough to support unassisted breathing.

49. Compression of gases allows more molecules of gas to be trapped in cylinder. This ensures that the gas will last longer when it is released. A regulator is used so that a proper amount of gas is delivered to the patient without harming them.

50. a. Scientists think that perhaps it is because they have developed a circulatory system that removes the nitrogen that forms bubbles and comes out in blood.

b. lung volume at depth of 500.0 m: 1.1×10^2 L; lung volume at a depth of 1.0×10^3 m: 51 L

51. a. Activities and devices such as the use of propellant chemicals, particularly CFCs, in spray cans, cleaning products for electronics parts and equipment, refrigerants, and foam insulation, mostly in the past, are associated with ozone depletion. Current use of methyl bromide for pest control in agriculture is also associated with ozone depletion. In short, CFCs and other industrial compounds containing chlorine and bromine have contributed to this problem.

b. The United States Environmental Protection Agency, under the Significant New Alternatives Policy (SNAP) program, has prepared an extensive listing and evaluation of alternatives. Students may choose from hundreds of compounds for their answers.

c. The Brewer measures total ozone and the amount of sulfur dioxide in the atmosphere. A good source of information for student research is the Environment Canada website, which contains an outline of the use of the Brewer as part of its history of Ozone and Ultraviolet Research and Monitoring.

52. Examples of suitable answers include walking and bike riding, driving (or choosing to drive in) vehicles certified under Ontario's Drive Clean program, and purchasing products known to have been produced in an environmentally (and atmospherically) responsible manner.

Unit 5 Self-Assessment Questions

(Student textbook pages 590–1)

1. a

2. a

3. c

4. c

5. c

6. b

7. d

8. e

9. e

10. d

11. The molecular gas composition varies, and different atoms have different masses, so 1 L of different gases will have different masses.

12. Bar graphs should reflect the percent composition of the top six components given in Table 12.5.

13. a. height of liquid gallium: 1.68×10^3 mmHg

b. Mercury was the only metal known in the time period to be liquid at room temperature, and it has a high density, so the column of mercury to be studied or measured did not need to be very long.

14. 27 L

15. Sketches should indicate that decreasing temperature results in decreased molecular motion. Molecules hit the side of the container less frequently. The pressure inside the bottle is now less than atmospheric pressure, so the bottle partially collapses.

16. 21°C

17. a. (B) > (C) > (A); flask (B) has 9 particles of gas in half the volume, flask (C) has 12 particles of gas in larger volume and flask (A) has 9 particles of gas in larger volume.

b. insert three more particles of gas

c. Some particles of gas will move to A, until equal pressure exists in each flask, when the number of particles in A equals twice the number of particles in B.

d. Some particles of blue and red gas will move to C, until equal pressure exists in each flask, when the number of particles in C equals twice the number of particles in B.

18. 7.0×10^3 kPa

19. a. no; after removal of a certain amount of gas the pressure in the cylinder has been has become the same as the atmospheric pressure.

b. 1.2 mol **c.** 32 g **d.** 7.5×10^{23} molecules

e. Yes, but the container would have to be put at an external pressure that is below the pressure of the container, and this continued so the pressure of the acetylene gas in the container is always higher than the external pressure.

20. 2700 m^3

21. a. More people using public transit would mean fewer cars on the road, which would help to reduce the levels of vehicle emissions. It would also help in urban and suburban areas where traffic congestion is the greatest and poses even higher local health risks.

b. Possible limitations include: availability in rural areas; availability within specific regions in cities or towns; fare costs vs. cost of private transit; availability in off-peak hours; and safety of passengers late at night.

22. a. 97.8 kPa **b.** 0.0103 mol CO_2(g)

c. 0.0103 mol X_2CO_3(s)

d. molar mass of carbonate: 1.38×10^2 g/mol **e.** The element represented by *X* is potassium.