**Unit 2 Forms of Matter: Gases**
**Chapter 4 Exploring Gas Laws**
**Solutions to Practice Problems**

**1.**
**Problem**
A sample of gas has a volume of 525 mL at 300 K and 746 mmHg. Find the volume if the temperature increases to 350 K and the pressure increases to 780 mmHg.

**What is Required?**
You must find the final volume, $V_2$, at the new temperature and pressure conditions.

**What is given**?
The initial conditions are:
$V_1$= 525 mL
$T_1$ = 300 K
$P_1$ = 746 mmHg
The final conditions are:
$T_2$ = 350 K
$P_2$ = 780 mmHg

**Plan Your Strategy**
Use the combined gas law to solve for the final volume, $V_2$.

**Act on Your Strategy**

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{746\,\text{mmHg} \times 525\,\text{mL} \times 350\,\text{K}}{300\,\text{K} \times 780\,\text{mmHg}} = 586\text{ mL}$$

**Check Your Solution**
The increase in temperature will cause the volume to increase, and the increase in pressure will cause the volume to decrease. The final volume is slightly larger than the initial volume, meaning that the temperature effect was greater. The answer seems reasonable, has the correct units (mL), and has the correct number of significant digits (3).

**2.**
**Problem**
A sample of gas has a volume of 75 mL at 19.0 $^{o}$C and 120 kPa. Predict what its volume would be at 25 $^{o}$C and 100 kPa.

**What is Required?**
You must find the final volume, $V_2$, at the new temperature and pressure conditions.

**What is given**?
The initial conditions are:
$V_1$= 75 mL
$t_1$ = 19.0 °C
$P_1$ = 120 kPa
The final conditions are:
$t_2$ = 25 °C
$P_2$ = 100 kPa

**Plan Your Strategy**
Use the combined gas law to solve for the final volume, $V_2$. Change the Celsius temperatures to Kelvin using the relationship
$T$ (Kelvin) = $t$(Celsius) + 273.15

**Act on Your Strategy**
$T_1$ = 19.0 °C + 273.15 = 273.15 K
$T_2$ = 25 °C + 273.15 = 298.15 K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{120\,\text{kPa} \times 75\,\text{mL} \times 298.15\ \text{K}}{292.15\,\text{K} \times 100\,\text{kPa}}$$
= 91.8mL or 92 mL (to agree with 2 significant digits in 25 °C)

**Check Your Solution**
The increase in temperature and the decrease in pressure both cause the volume to increase. The answer seems reasonable, has the correct units (mL), and has the correct number of significant digits (2).

**3.**
**Problem**
A chemical researcher produces 15 mL of a new gaseous substance in a laboratory at a temperature of 25 °C and a pressure of 100 kPa. Predict the volume of this gas if the temperature was changed to 0 °C and the final pressure was 101.325 kPa.

**What is Required?**
You must find the final volume, $V_2$, at the new temperature and pressure conditions.

**What is given**?
The initial conditions are:
$V_1$= 15 mL
$t_1$ = 25 °C
$P_1$ = 100 kPa
The final conditions are:

$t_2 = 0.0\ ^{o}C$
$P_2 = 101.325$ kPa

**Plan Your Strategy**
Use the combined gas law to solve for the final volume, $V_2$. Change the Celsius temperatures to Kelvin using the relationship
$T$ (Kelvin) = $t$(Celsius) + 273.15

**Act on Your Strategy**
$T_1 = 25\ ^{o}C + 273.15 = 298.15$ K
$T_2 = 0\ ^{o}C + 273.15 = 273.15$ K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{100\,\text{kPa} \times 15\,\text{mL} \times 273.15\ \text{K}}{298.15\,\text{K} \times 101.325\,\text{kPa}} = 14\ \text{mL}$$

**Check Your Solution**
The decrease in temperature and the increase in pressure both cause the volume to decrease. The answer seems reasonable, has the correct units (mL), and has the correct number of significant digits (2).

**4.**
**Problem**
A 2.7 L sample of nitrogen gas is collected at a temperature of 45.0 $^{o}$C and a pressure of 0.92 atm. What pressure would have to be applied to the gas to reduce its volume to 2.0 L at a temperature of 25.0 $^{o}$C?

**What is Required?**
You must find the final pressure, $P_2$, at the new temperature and volume conditions.

**What is given**?
The initial conditions are:
$V_1 = 2.7$ L
$t_1 = 45.0\ ^{o}C$
$P_1 = 0.92$ atm
The final conditions are:
$V_2 = 2.0$ L
$t_2 = 25\ ^{o}C$

**Plan Your Strategy**
Use the combined gas law to solve for the final pressure, $P_2$. Change the Celsius temperatures to Kelvin using the relationship
$T$ (Kelvin) = $t$(Celsius) + 273.15

**Act on Your Strategy**
$T_1 = 45.0\ ^{o}C + 273.15 = 318.15\ K$
$T_2 = 25.0\ ^{o}C + 273.15 = 298.15\ K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_2 = \frac{P_1V_1T_2}{T_1V_2} = \frac{0.92\ \text{atm} \times 2.7\ \text{L} \times 298.15\ \text{K}}{318.15\ \text{K} \times 2.0\ \text{L}} = 1.2\ \text{atm}$$

**Check Your Solution**
The final pressure is greater than the initial pressure. A decrease in temperature and an increase in pressure will decrease the volume. The answer seems reasonable, has the correct units (atm), and has the correct number of significant digits (2).

**5.**
**Problem**
A sample of argon gas occupies a volume of 2.0 L at −35 °C and standard atmospheric pressure. What would its Celsius temperature be at 2.0 atm if its volume decreased to 1.5 L?

**What is Required?**
You must find the final Celsius temperature, $t_2$, at the new volume and pressure conditions.

**What is given**?
The initial conditions are:
$V_1 = 2.0\ L$
$t_1 = -35\ ^{o}C$
$P_1$ = standard pressure = 1.0 atm
The final conditions are:
$V_2 = 1.5\ L$
$P_2 = 2.0\ atm$

**Plan Your Strategy**
Change the initial Celsius temperature to Kelvin using the relationship
$T$ (Kelvin) = $t$(Celsius) + 273.15
Use the combined gas law to solve for the final Kelvin temperature, $T_2$. Change the final Kelvin temperature back to Celsius using the relationship
$t$(Celsius) = $T$ (Kelvin) – 273.15

**Act on Your Strategy**
$T_1 = -35\ ^{o}C + 273.15 = 238.15\ K$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$T_2 = \frac{P_2V_2T_1}{P_1V_1} = \frac{2.0\,\text{atm} \times 1.5\ \text{L} \times 238.15\ \text{K}}{1.0\ \text{atm} \times\ 2.0\,\text{L}} = 357.225\ \text{K}$$

$t_2$ = 357.225 K – 273.15 = 84 $^{o}$C

**Check Your Solution**
The increase in pressure will cause the volume to decrease, and the increase in temperature will cause the volume to increase. The pressure effect must be greater than the temperature effect, since the volume decreases. The answer seems reasonable, has the correct units ($^{o}$C), and has the correct number of significant digits (2).

**6.**
**Problem**
A 500 mL sample of oxygen is kept at 950 mmHg and 21.5 $^{o}$C. The oxygen is expanded to a volume of 700 mL and the temperature is adjusted until the pressure is 101.325 kPa. Predict the final temperature of the oxygen gas.

**What is Required?**
You must find the final Celsius temperature, $t_2$, at the new volume and pressure conditions.

**What is given**?
The initial conditions are:
$V_1$ = 500 mL
$t_1$ = 21.5 $^{o}$C
$P_1$ = 950 mmHg
The final conditions are:
$V_2$ = 700mL
$P_2$ = 101.325 kPa = 760 mmHg

**Plan Your Strategy**
The pressure units are not the same, so you must convert P2 into millimetres of mercury using the conversion 760 mmHg = 101.325 kPa.
Change the initial Celsius temperature, $t_1$, to Kelvin using the relationship
$T$ (Kelvin) = $t$(Celsius) + 273.15
Use the combined gas law to solve for the final Kelvin temperature, $T_2$.
Change the final Kelvin temperature, $T_2$, back to Celsius using the relationship
$t$(Celsius) = $T$ (Kelvin) – 273.15

**Act on Your Strategy**
$T_1$ = 21.5 $^{o}$C + 273.15 = 294.65 K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$T_2 = \frac{P_2V_2T_1}{P_1V_1} = \frac{760\,\text{mmHg} \times 700\,\text{mL} \times 294.65\text{ K}}{950\,\text{mmHg} \times 500\,\text{mL}} = 330.008\text{ K}$$

$t_2 = 330.008\text{ K} - 273.15 = 56.9\ ^{o}\text{C}$

**Check Your Solution**

The final temperature is greater than the initial temperature. The increase in temperature and the decrease in pressure will both cause the volume to increase. The answer seems reasonable, has the correct units ($^{o}$C), and has the correct number of significant digits (3).

**7.**

**Problem**

What volume of water vapour forms when 250 mL of hydrogen reacts with 125 mL of oxygen?

**What is required?**

You must calculate the volume of water vapour that is produced when hydrogen and oxygen gas react if all the gases are at the same temperature and pressure conditions.

**What is Given?**

The volumes of the hydrogen and oxygen gas and the whole-number ratio of hydrogen to oxygen to water are known.

**Plan Your Strategy**

For the reaction between hydrogen gas and oxygen gas to produce water vapour, the Law of Combining Volumes gives the whole-number ratio of hydrogen to oxygen to water as 2:1:2. Substitute the given volumes of hydrogen and oxygen in this ratio and solve for the volume of water vapour produced.

**Act on Your Strategy**

$\frac{\text{hydrogen}}{\text{water}} : \frac{2}{2} = \frac{250\,\text{mL}}{x}$ $x = 250$ mL **OR** $\frac{\text{oxygen}}{\text{water}} : \frac{1}{2} = \frac{125\,\text{mL}}{x}$ $x = 250$ mL

**Check Your Solution**

The ratio of hydrogen to oxygen to water of 250 mL:125 mL:250 mL is the same as the known whole-number ratio of 2:1:2 .

**8.**

**Problem**

What volume of nitrogen gas forms when the decomposition of ammonia gas produces 15 mL of hydrogen gas?

**What is required?**
You must calculate the volume of nitrogen gas that is produced when ammonia decomposes to nitrogen and hydrogen if all the gases are at the same temperature and pressure conditions.

**What is Given?**
The volume of hydrogen gas and the whole-number ratio of ammonia to nitrogen to hydrogen are known.

**Plan Your Strategy**
For the reaction of ammonia gas decomposing to nitrogen and hydrogen, the Law of Combining Volumes gives the whole-number ratio of ammonia to nitrogen to hydrogen as 2:1:3. Substitute the given volume of hydrogen in this ratio and solve for the volume of nitrogen produced.

**Act on Your Strategy**

$$\frac{\text{hydrogen}}{\text{nitrogen}}:\frac{3}{1}=\frac{15\,\text{mL}}{x} \qquad x = 5.0\text{ mL}$$

**Check Your Solution**
The ratio of hydrogen to nitrogen of 15 mL:5.0 mL is the same as the known whole-number ratio of 3:1.

**9.**
**Problem**
A chemist performed an experiment and determined that 125 mL of nitrogen gas reacted with 250 mL of oxygen gas and formed 250 mL of nitrogen dioxide gas. What volume of nitrogen dioxide gas is formed when 350 mL of nitrogen gas reacts with an excess of oxygen gas?

**What is required?**
You must calculate the volume of nitrogen dioxide gas that is formed when nitrogen gas reacts with an excess of oxygen gas.

**What is Given?**
The volume of nitrogen gas and the ratios of nitrogen gas to oxygen gas to nitrogen dioxide gas are known.

**Plan Your Strategy**
For the reaction between nitrogen gas and oxygen gas to produce nitrogen dioxide gas, the Law of Combining Volumes gives the whole-number ratio of nitrogen to oxygen to nitrogen dioxide gas as 1:2:2. Substitute the given volumes of nitrogen and oxygen in this ratio and solve for the volume of nitrogen dioxide gas produced.

**Act on Your Strategy**

$$\frac{\text{nitrogen gas}}{\text{nitrogen dioxide gas}} = \frac{1}{2} = \frac{350}{x}$$

$x = 700$ mL

**Check Your Solution**
With an excess of oxygen gas, the ratio of nitrogen gas to nitrogen dioxide gas of 350 mL:700 mL is the same as the known whole-number ratio of 1:2.

**10.**
**Problem**
What is the pressure on the gas when 3.25 mol of hydrogen gas occupy a volume of 67.5 L at a temperature of 295 K?

**What is Required?**
You must calculate the pressure exerted by a sample of hydrogen gas.

**What is Given?**
number of moles = $n$ = 3.25 mol
volume = $V$ = 67.5 L
temperature = $t$ = 22.0 $^{\circ}$C
universal gas constant = $R = 8.314 \ \frac{\text{k} \bullet \text{Pa} \bullet \text{L}}{\text{mol} \bullet \text{K}}$

**Plan Your Strategy**
Use the ideal gas law to solve for pressure.

**Act on Your Strategy**
$PV = nRT$

$$P = \frac{nRT}{V} = \frac{3.25\,\text{mol} \times 8.314\,\text{kPa L/mol K} \times 295\,\text{K}}{67.5\,\text{L}} = 118 \text{ kPa}$$

**Check Your Solution**
The answer has the correct units (kPa) and the correct number of significant digits (3).

**11.**
**Problem**
What is the volume of 5.65 mol of helium gas at 98 kPa of pressure and a temperature of 18.0 $^{\circ}$C?

**What is Required?**
You must calculate the volume of helium gas in a given number of moles.

**What is Given?**
number of moles = $n$ = 5.65 mol

pressure = $P$ = 98 kPa
temperature = $t$ = 18.0 ºC

universal gas constant = $R$ = $8.314 \frac{kPa \cdot L}{mol \cdot K}$

**Plan Your Strategy**
Use the ideal gas law to determine the volume of helium in the sample.
Convert the Celsius temperature to Kelvin using the expression
$T$ (Kelvin) = $t$(Celsius) + 273.15

**Act on Your Strategy**

$$PV = nRT$$

$$\frac{\cancel{P}V}{\cancel{P}} = \frac{nRT}{P}$$

$$V = \frac{nRT}{P}$$

$$V = \frac{(5.65\,mol)(8.314\frac{kPa \cdot L}{mol \cdot K})(18.0 + 273.15\,K)}{98\,kPa}$$

$$V = 1.4 \times 10^{2}\ L$$

**Check Your Solution**
The answer has the correct units (L) and the correct number of significant digits (2).

**12.**
**Problem**
How many moles of ammonia are present in a 250 mL container at 25.0 $^{o}$C and 0.100bar?

**What is Required?**
You must calculate the number of moles in a sample of ammonia.

**What is Given?**
volume = $V$ = 250 mL
temperature = $t$ = 25.0 $^{o}$C
pressure = $P$ = 0.100 bar
universal gas constant = $R$ = 8.314 $\frac{\text{kPa L}}{\text{mol K}}$

**Plan Your Strategy**
Convert the Celsius temperature to Kelvin using the expression
$T$ (Kelvin) = $t$(Celsius) + 273.15
Convert the volume of 250 mL to litres using the conversion 1000 mL = 1 L.
Convert 0.100 bar to kPa using the conversion that 1 bar = 100 kPa.

Use the ideal gas law to solve for the number of moles, *n*.

**Act on Your Strategy**
$T = 25.0^{o}C + 273.15 = 298.15$ K

$$250 \text{ mL} \times \frac{1 \text{L}}{1\ 000 \text{mL}} = 0.250 \text{ L}$$

$$0.100 \text{ bar} \times \frac{100 \text{kPa}}{1 \text{bar}} = 10.0 \text{ kPa}$$

$PV = nRT$

$$n = \frac{PV}{RT} = \frac{10.0 \text{kPa} \times 0.250 \text{L}}{8.314 \text{kPa L/mol K} \times 298.15 \text{K}} = 1.02 \times 10^{-3} \text{ mol}$$

**Check Your Solution**
The answer has the correct units (mol) and the correct number of significant digits (3).

**13.**
**Problem**
Find the volume of 1.87 g of methane gas ($CH_4$) at 20.0 $^{o}$C and 780 mmHg.

**What is required?**
You must calculate the volume of a given mass of methane.

**What is Given?**
The gas is methane, $CH_4$.
mass = $m$ = 1.87 g
temperature = $t$ = 20.0 $^{o}$C
pressure = $P$ = 780 mmHg
universal gas constant = $R = 8.314 \ \frac{\text{kPa L}}{\text{mol K}}$

**Plan Your Strategy**
Convert the Celsius temperature to Kelvin using the expression
$T$ (Kelvin) = $t$(Celsius) + 273.15
Convert 780 mmHg to kilopascals using the conversion 760 mmHg = 101.325 kPa.
Using the chemical formula $CH_4$, calculate the molar mass of methane.
Using the ideal gas law, $PV = nRT$, and $n = \frac{m}{M}$, rearrange the ideal gas law to an expression for volume, $V$.

**Act on Your Strategy**
$T = 20.0^{o}C + 273.15 = 293.15$ K

$$780\text{ mmHg} \times \frac{101.325\,\text{kPa}}{760\,\text{mmHg}} = 103.991\text{ kPa}$$

Molar mass, $M$, for $CH_4$ = 16.05 g/mol

$$PV = nRT = \frac{m}{M}RT$$

$$V = \frac{mRT}{PM} = \frac{1.87\,\text{g} \times 8.314\,\text{kPa L/mol K} \times 293.15\,\text{K}}{103.991\,\text{kPa} \times 16.05\,\text{g/mol}} = 2.73\text{ L}$$

**Check Your Solution**

The answer has the correct units (L) and the correct number of significant digits (3).

**14.**

**Problem**

What is the Kelvin temperature of 0.063 mg of argon gas at 1.25 atm of pressure if its volume is 31.5 mL?

**What is Required?**

You must find the temperature of a given mass of argon gas, Ar(g).

**What is Given?**

mass = $m$ = 0.063 mg
pressure = $P$ = 1.25 atm
volume = $V$ = 31.5 mL
universal gas constant = $R = 8.314\,\frac{kPa \cdot L}{mol \cdot K}$

**Plan Your Strategy**

Use a periodic table to find the molar mass, $M$, for argon (Ar).
Convert 0.063 mg to grams using the conversion 1 mg = 0.001 g.
Convert 1.25 atm to kilopascals using the conversion 1 atm = 101.325 kPa.
Convert 31.5 mL to litres using the conversion 1000 mL = 1 L.
Combine the ideal gas law and the equation $n = \frac{m}{M}$.
Rearrange the overall equation to solve for $T$.

**Act on Your Strategy**

Molar mass, $M$, for Ar = 39.95 g/mol

$$0.063\,mg \times \frac{1\,g}{1000\,mg} = 0.000\,063\,g \;\; or \;\; 6.3 \times 10^{-5}\,g$$

$$31.5\,mL \times \frac{1\,L}{1000\,mL} = 0.0315\,L$$

$$PV = \frac{m}{M}RT$$

$$T = \frac{PVM}{mR}$$

$$T = \frac{(1.25\,atm)(101.325\frac{kPa}{atm})(0.0315\,L)(39.95\frac{g}{mol})}{(6.3 \times 10^{-5}\,g)(8.314\frac{kPa \cdot L}{mol \cdot K})}$$

$$T = 304\,301\,K$$

$$T = 3.0 \times 10^{5}\,K$$

**Check Your Solution**
The answer has the correct units (K) and the correct number of significant digits (2).

**15.**
**Problem**
Find the Celsius temperature of nitrogen gas if a 5.60 g sample occupies 2400 mL at 3.00 atm of pressure?

**What is required?**
You must calculate the temperature, in Celsius, of a sample of nitrogen gas.

**What is Given?**
The gas is nitrogen, $N_2$.
mass = $m$ = 5.60 g
pressure = $P$ = 3.00 atm
volume = $V$ = 2 400 mL
universal gas constant = $R$ = 8.314 $\frac{\text{kPa L}}{\text{mol K}}$

**Plan Your Strategy**
Convert 3.00 atm to kPa using the conversion 1.00 atm = 101.325 kPa.
Using the chemical formula, $N_2$, calculate the molar mass of nitrogen.
Change the volume of 2 400 mL to litres using the conversion 1000 mL = 1 L
Using the ideal gas equation, $PV = nRT$, and $n = \frac{m}{M}$, rearrange the ideal gas law to an expression for the Kelvin temperature, $T$.

Determine the Celsius temperature using the expression
$t$(Celsius) = $T$ (Kelvin) − 273.15

**Act on Your Strategy**

$$3 \text{ atm} \times \frac{101.325 \text{ kPa}}{1 \text{ atm}} = 303.975 \text{ kPa}$$

Molar mass, $M$, for $N_2$ = 28.02 g/mol

$$2\,400 \text{ mL} \times \frac{1 \text{ L}}{1000 \text{ mL}} = 2.400 \text{ L}$$

$$PV = nRT = \frac{m}{M}RT$$

$$T = \frac{PVM}{mR} = \frac{303.975 \text{ kPa} \times 2.400 \text{ L} \times 28.02 \frac{g}{mol}}{5.60 \text{ g} \times 8.314 \text{ kPa L/mol K}} = 439.06 \text{ K}$$

$t$ = 439.06 K − 273.15 = 165.91 °C = 166 °C

**Check Your Solution**

The answer has the correct units (°C) and the correct number of significant digits (3).

**16.**

**Problem**

A sample of a gas with a mass of 0.571 g has a volume of 375 mL at 99.0 kPa and 23.8 °C. Find the molar mass of the gas.

**What is required?**

You must calculate the molar mass of a sample of gas.

**What is Given?**

mass = $m$ = 0.571 g
temperature = $t$ = 23.8 °C
pressure = $P$ = 99.0 kPa
universal gas constant = $R$ = 8.314 $\frac{\text{kPa L}}{\text{mol K}}$

**Plan Your Strategy**

Convert the Celsius temperature to Kelvin using the expression
$T$ (Kelvin) = $t$(Celsius) + 273.15
Change the volume of 375 mL to litres using the conversion 1000 mL = 1 L.
Using the ideal gas equation, $PV = nRT$, and $n = \frac{m}{M}$, rearrange the ideal gas law to an expression for molar mass, $M$.

**Act on Your Strategy**

$T = 23.8\ ^{\circ}\text{C} + 273.15 = 296.95\ \text{K}$

$$375\ \text{mL} \times \frac{1\ \text{L}}{1\,000\ \text{mL}} = 0.375\ \text{L}$$

$$PV = nRT = \frac{m}{M}RT$$

$$M = \frac{mRT}{PV} = \frac{0.571\ \text{g} \times 8.314\ \text{kPa L/mol K} \times 296.95\ \text{K}}{99.0\ \text{kPa} \times 0.375\ \text{mL}} = 38.0\ \text{g/mol}$$

**Check Your Solution**

The answer has the correct units (g/mol) and the correct number of significant digits (3).

**17.**

**Problem**

Calculate the density of carbon dioxide gas at SATP to three significant digits.

**What is Required?**

You must calculate the density of carbon dioxide gas at SATP to three significant digits.

**What is Given?**

The gas, carbon dioxide, is given.
$T = 298.15$ K
$P = 100$ kPa

**Plan Your Strategy**

Recall that SATP is 100 kPa and 298.15 K.

Recall the formula for density $D = \frac{m}{V}$.

Start with the ideal gas law $PV = nRT$.

Because $n = \frac{m}{M}$, you can substitute $\frac{m}{M}$ for $n$ in the ideal gas law $PV = \frac{mRT}{M}$.

Since density is defined as the mass per unit volume, solve for $\frac{m}{V}$. Rearrange the above equation to get

$$PV\left(\frac{M}{RT}\right)\left(\frac{1}{V}\right) = \frac{mRT}{M}\left(\frac{M}{RT}\right)\left(\frac{1}{V}\right)$$

$$\frac{PM}{RT} = \frac{m}{V} = D$$

For gases, the density is usually given in grams per litre, so let be $V = 1.0$ L.

**Act on Your Strategy**

$M CO_2(g) = 44.01 \frac{g}{mol}$

$$\frac{PM}{RT} = \frac{m}{V}$$

$$\frac{100\text{ KPa} \times 44.01 \frac{\text{g}}{\text{mol}}}{8.314 \frac{\text{KPa} \bullet \text{L}}{\text{mol} \bullet \text{K}} \times 298.15\text{ K}} = \frac{m}{V} = D$$

$\text{D} = 1.775 \frac{\text{g}}{\text{L}} \approx 1.78 \frac{\text{g}}{\text{L}}$

**Check Your Solution**

The answer seems to be reasonable, has the correct units ($\frac{\text{g}}{\text{L}}$), and the correct number of significant digits (3).

**18.**
**Problem**
What is the density of helium gas at –25 °C and a pressure of 90 kPa?

**What is Required?**
You must calculate the density of helium gas at –25 °C and a pressure of 90 kPa.

**What is Given?**
Helium gas, He(g), is given.
$t$ = –25 °C
$P$ = 90 kPa

**Plan Your Strategy**
Convert the Celsius temperature to Kelvin using $T = t + 273.15$.

Recall the formula for density $D = \frac{m}{V}$.

Start with the ideal gas law $PV = nRT$.

Because $n = \frac{m}{M}$, you can substitute $\frac{m}{M}$ for $n$ in the ideal gas law $PV = \frac{mRT}{M}$.

Since density is defined as the mass per unit volume, solve for $\frac{m}{V}$. Rearrange the above equation to get

$$PV\left(\frac{M}{RT}\right)\left(\frac{1}{V}\right) = \frac{mRT}{M}\left(\frac{M}{RT}\right)\left(\frac{1}{V}\right)$$

$$\frac{PM}{RT} = \frac{m}{V} = D$$

For gases, the density is usually given in grams per litre, so let be $V$ = 1.0 L.

**Act on Your Strategy**

$M\text{He(g)} = 4.00\,\frac{\text{g}}{\text{mol}}$

$T = t + 273.15 = –25\ °\text{C} + 273.15 = 248.15\ \text{K}$

$$\frac{PM}{RT} = \frac{m}{V}$$

$$\frac{90\ \text{KPa} \times 4.00\,\frac{\text{g}}{\text{mol}}}{8.314\,\frac{\text{KPa} \bullet \text{L}}{\text{mol} \bullet \text{K}} \times 248.15\ \text{K}} = \frac{m}{V} = D$$

$$\text{D} = 0.17449\,\frac{\text{g}}{\text{L}} \approx 0.17\ \frac{\text{g}}{\text{L}}$$

**Check Your Solution**

The answer seems to be reasonable, has the correct units ($\frac{\text{g}}{\text{L}}$), and the correct number of significant digits (2).

**19.**
**Problem**
What is the pressure on water vapour at 150 °C if its density is 0.500 g/L?

**What is Required?**
You must calculate the pressure on water vapour at 150 °C if its density is 0.500 g/L.

**What is Given?**
Water vapour, $H_2O(g)$, is given.
$t = 150\ °\text{C}$
$D = 0.500\ \text{g/L}$

**Plan Your Strategy**
Convert the Celsius temperature to Kelvin using $T = t + 273.15$.

Recall the formula for density $D = \frac{m}{V}$.

Start with the ideal gas law $PV = nRT$.

Because $n = \frac{m}{M}$, you can substitute $\frac{m}{M}$ for $n$ in the ideal gas law $PV = \frac{mRT}{M}$.

Rearrange the above equation to solve for $P$

$$PV\left(\frac{1}{V}\right) = \frac{mRT}{M}\left(\frac{1}{V}\right)$$

$$P = \frac{mRT}{MV}$$

**Act on Your Strategy**

$MH_2O(g) = 18.02\,\frac{\text{g}}{\text{mol}}$

$T = t + 273.15 = 150\ °\text{C} + 273.15 = 423.15\ \text{K}$

$$P = \frac{mRT}{MV}$$

$$P = \frac{0.500\ \text{g} \times 8.314\,\frac{\text{KPa} \bullet \text{L}}{\text{mol} \bullet \text{K}} \times 423.15\ \text{K}}{18.02\,\frac{\text{g}}{\text{mol}} \times 1\ \text{L}}$$

P = 97.615 KPa ≈ 97.6 KPa

**Check Your Solution**

The answer seems to be reasonable, has the correct units (KPa), and the correct number of significant digits (3).