Name: ______________________________

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Chemistry 20
Gases Workbook

Basic Conversions

1. Convert the following:

$\frac{101.325\,kPa}{760\,torr} = \frac{124.46\,kPa}{x}$ a) 124.46 kPa = 933.53 torr

$\frac{1\,atm}{760\,mmHg} = \frac{3.25\,atm}{x}$ b) 3.25 atm = 2.47×10^3 mm Hg

$101.325\,kPa = 1\,atm = 760\,mmHg$
$760\,torr = 1.01325\,bar$

c) 100.50 torr = 100.50 mm Hg

$\frac{1\,atm}{101.325\,kPa} = \frac{2.85\,atm}{x}$ d) 2.85 atm = 289 kPa

e) 550 mm Hg = 550 torr

2. Convert the following temperatures:

a) 100 °C = 373 K
+273

b) 100 K = −173 °C
−273

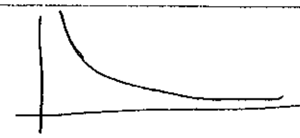
c) 25.00 °C = 298.0 K
+273

d) 509.27 K = 236.27 °C
−273

e) –45.37 °C = 227.6 K
+273

* When doing unit conversions the answer in new units has the same # of sig. dig as the original.

Boyle's Law $P_1V_1 = P_2V_2$



1. A sample of hydrogen gas has a volume of 0.300 L. If it is compressed into a volume of 0.200 L with at pressure of 300 kPa, what was the initial pressure on the gas? Assume constant temperature.

$P_1 = ?$
$V_1 = 0.300 L$
$P_2 = 300 kPa$
$V_2 = 0.200 L$

$P(0.300) = (300)(0.200)$

$\boxed{P_1 = 200 \text{ kPa}}$

2. Nitrogen in a 250 mL container at 65.0 kPa is transferred to a container with a volume of 600 mL. Calculate the new pressure if the temperature is kept constant.

$V_1 = 250 mL$
$P_1 = 65.0 kPa$
$V_2 = 600 mL$
$P_2 = ?$

$P_1V_1 = P_2V_2$
$(65.0)(250) = P_2(600)$

$\boxed{P_2 = 27.1 \text{ kPa}}$

3. A 600 mL sample of $HCl_{(g)}$ has a pressure of 150 kPa. If it is transferred to a vessel with a volume of 0.350 L, what is the new pressure?

$P_1 = 150 kPa$
$V_1 = 600 mL$
$P_2 = ?$
$V_2 = 350 mL$

$(150)(600) = P_2(350)$

$\boxed{P_2 = 257 \text{ kPa}}$

4. A 1.5 L container is filled with argon gas at a pressure of 1.5 atm. What is the final volume if the pressure is dropped to 0.85 atm?

$P_1 = 1.5 atm$
$V_1 = 1.5 L$
$P_2 = 0.85 atm$
$V_2 = ?$

$P_1V_1 = P_2V_2$
$(1.5)(1.5) = (0.85)V_2$

$\boxed{V_2 = 2.6 \text{ L}}$

5. The volume of a weather balloon is 30.0 L after the pressure has been changed from 785 mmHg to 742 mmHg. What was the original volume of the balloon?

$P_1 = 785 mmHg$
$V_1 = ?$
$P_2 = 742 mmHg$
$V_2 = 30.0 L$

$(785)(V_1) = (742)(30.0)$

$\boxed{V_1 = 28.4 \text{ L}}$

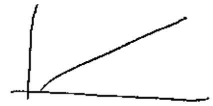
6. A flexible container has a volume of 10.0L. If the pressure is tripled, what will the new volume be?

$P_1 = 1$
$V_1 = 10.0$
$P_2 = 3$
$V_2 = ?$

$1(10.0) = 3(V_2)$

$\boxed{V_2 = 3.33 \text{ L}}$

Charles' Law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$



1. A 400 mL sample of a gas at 10°C is warmed to 25°C at a constant pressure. Calculate the final volume assuming constant pressure.

$V_1 = 400\text{ mL}$
$T_1 = 10°C + 273 = 283\text{ K}$
$V_2 = ?$
$T_2 = 25°C + 273 = 298\text{ K}$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\quad \frac{400\text{ mL}}{283\text{ K}} = \frac{x\text{ mL}}{298}$

$V_2 = 4.2 \times 10^2\text{ mL}$

2. A sealed syringe contains 25.0 mL of trapped air at 20.0°C. If the sun shines on the syringe and the volume increases to 26.8 mL, what is the new temperature?

$V_1 = 25\text{ mL}$
$T_1 = 20°C = 293\text{ K}$
$V_2 = 26.8\text{ mL}$
$T_2 = ?$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\quad \frac{25\text{ mL}}{293\text{ K}} = \frac{26.8\text{ mL}}{x}$

$T_2 = 314\text{ K}$

3. A 45.0 L sample of gas is under a pressure of 4.50 atm. If the original pressure was 6.25 atm, what was the original volume?

$V_1 = ?$
$P_1 = 6.25\text{ atm}$
$V_2 = 45.0\text{ L}$
$P_2 = 4.50\text{ atm}$

$P_1V_1 = P_2V_2$
$6.25(V_1) = 4.50(45.0)$

$V_1 = 32.4\text{ L}$

4. A balloon is filled to a volume of 1.5 L at room temperature (23°C). The balloon will burst if it reaches a volume of 2.0 L. A student takes the balloon outside where the air temperature is 39°C. Does the balloon burst?

$V_1 = 1.5\text{ L}$
$T_1 = 23°C + 273 = 296\text{ K}$
$V_2 = ?$
$T_2 = 39°C + 273 = 312\text{ K}$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\quad \frac{1.5}{296} = \frac{V_2}{312}$

$V_2 = 1.58\text{ L}$
Balloon does not burst!

5. The volume of a gas is originally 15 L. If the temperature is quadrupled, what will the new volume be?

$V_1 = 15\text{ L}$
$T_1 = 1$
$V_2 = x$
$T_2 = 4$

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ $\quad \frac{15}{1} = \frac{x}{4}$

$x = 60\text{ L}$
(Will quadruple as well)

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

Combined Gas Law

1. A 450 mL sample of freon gas at 1.50 atm ant 15°C was compressed to 300 mL at a pressure of 2.00 atm. Calculate the final temperature in degrees Celcius.

$P_1 = 1.50 atm$
$V_1 = 450 mL$
$T_1 = 15°C + 273 = 288 K$
$P_2 = 2.00 atm$
$V_2 = 300 mL$
$T_2 = ?$

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

$$\frac{(1.50)(450)}{288} = \frac{2.00(300)}{x}$$

$x = 256 K - 273$
$= -17°C$

2. A 2.75 L sample of helium gas at 99.0 kPa was heated from 21.0°C to 71.0 °C and the pressure changed to 100 kPa. Calculate the final volume.

$P_1 = 99.0 kPa$
$V_1 = 2.75 L$
$T_1 = 21°C + 273 = 294 K$
$P_2 = 100 kPa$
$V_2 = ?$
$T_2 = 71°C + 273 = 344 K$

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

$$\frac{(99)(2.75)}{294} = \frac{(100)V_2}{344}$$

$V_2 = 3.19 L$

3. Water vapour at 150°C is at 350 kPa in a 2.50 L storage tank. If the temperature drops to 95°C, what will the new pressure be assuming the volume does not change?

$P_1 = 350 kPa$
$V_1 = 2.50 L$
$T_1 = 150°C = 423 K$
$P_2 = ?$
$V_2 = 2.50$
$T_2 = 95°C = 368 K$

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

$$\frac{(350)(2.50)}{423} = \frac{P_2(2.50)}{368}$$

$P_2 = 304 kPa$

$3.0 \times 10^2 kPa$

4. A 10.0 L sample of propane is at 20.0°C and 150 kPa. What will the temperature be in °C if the pressure is increased to 300 kPa and the volume is decreased to 8.00 L?

$P_1 = 150 kPa$
$V_1 = 10.0 L$
$T_1 = 20.0°C + 273 = 293 K$
$P_2 = 300 kPa$
$V_2 = 8.00 L$
$T_2 = ?$

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

$$\frac{(150)(10.0)}{293} = \frac{(300)(8.00)}{T_2}$$

$T_2 = 468.8 K - 273$

196°C

5. In an engine, a fuel-air mixture at atmospheric pressure is compressed rapidly from 500 mL to 60 mL, while the temperature increases from 100 °C to 1000 °C. What is the new pressure of the mixture prior to ignition?

$P_1 = 1 atm$
$V_1 = 500 mL$
$T_1 = 100 + 273 = 373$
$P_2 = ?$
$V_2 = 60 mL$
$T_2 = 1000 + 273 = 1273$

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

$$\frac{1(500)}{373} = \frac{P_2(60)}{1273}$$

$P_2 = 28 atm$

6. A gas cylinder at a pressure of 1200 kPa has a safety valve that releases gas if the pressure exceeds 1700 kPa. At what temperature will the valve open if the initial temperature is 22 °C and the volume is 20 L?

$P_1 = 1200 kPa$
$V_1 = 20 L$
$T_1 = 22°C + 273 = 295 K$
$P_2 = 1700 kPa$
$V_2 = 20 L$

* size of cylinder does not change

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

$$\frac{1200(20)}{295} = \frac{(1700)(20)}{x}$$

$x = 417.9 K - 273 = 145°C$

*Volumes of reactant & produces are always in simple whole number ratios

Law of Combining Volumes

1. Xenon and fluorine gases react to produce solid crystals of xenon tetrafluoride according to the following equation:

$$Xe(g) + 2\,F_2(g) \rightarrow XeF_4(g)$$

V=? 85mL

What volume of fluorine is required to consume 85 mL of xenon?

$$\frac{2\text{ mL } F_2(g)}{1\text{ mL } Xe} = \frac{x}{85\text{ mL } Xe}$$

$$x = \boxed{170\text{ mL}}$$

2. The combustion of gasoline in an automobile engine is represented in the equation below. If 4.0 L of oxygen are consumed, what volume of each of the product gases will result?

$$2\,C_8H_{18}(\ell) + 25\,O_2(g) \rightarrow 16\,CO_2(g) + 18\,H_2O(g)$$

4.0 L

Volume $CO_2(g)$

$$\frac{25\text{ L } O_2}{16\text{ L } CO_2} = \frac{4.0\text{ L}}{x}$$

$$x = \boxed{2.6\text{ L } CO_2(g)}$$

volume $H_2O(g)$

$$\frac{25\text{ L } O_2(g)}{18\text{ L } H_2O(g)} = \frac{4.0\text{ L}}{x}$$

$$x = \boxed{2.9\text{ L } H_2O(g)}$$

3. Ammonia is made through the reaction of hydrogen gas with nitrogen gas. How much hydrogen gas is needed to produce 1.00×10^5 L of ammonia?

$$3\,H_2(g) + N_2(g) \rightarrow 2\,NH_3(g)$$

x = ? 1.00×10^5 L

$$\frac{3\text{ L } H_2(g)}{2\text{ mol } NH_3(g)} = \frac{x\text{ mol } H_2(g)}{1.00\times10^5\text{ L } NH_3}$$

$$\boxed{1.50\times10^5\text{ L } H_2(g)}$$

4. If 8.00 L of propane, $C_3H_8(g)$, is burned in a BBQ, what is the total volume of gaseous products produced?

$$C_3H_8(g) + 5\,O_2(g) \rightarrow 3\,CO_2(g) + 4\,H_2O(g)$$

$$\frac{1\text{ L } C_3H_8}{7\text{ L products}} = \frac{8.00\text{ L } C_3H_8}{x}$$

$$\boxed{x = 56.0\text{ L of gaseous products}}$$

$PV = nRT$ $R = 8.314 \frac{kPa \cdot L}{mol \cdot K}$ Ideal gas - volumes of molecules negligi
- no forces between molecu
- elastic collisions (energy conse
- does not condense.

Ideal Gas Law

1. What amount of air, in moles, is present in a house containing 6.00×10^5 L of air at 20°C and 98 kPa?

P = 98 KPa
V = 6.00×10^5 L
n = ?
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 20°C = 293K

$PV = nRT$
$98(6.00 \times 10^5) = n(8.314)(293)$
n = 24137.9 mol
2.4×10^4 mol or 24 Kmol

2. Calculate the volume of 16 mol of oxygen at 22°C and 97.5 kPa.

P = 97.5 KPa
V = ?
n = 16 mol
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 22°C = 295 K

$PV = nRT$
$97.5(V) = 16(8.314)(295)$
x = 402.48 L
4.0×10^2 L

3. A 70.0 L tank on a car is drained of *liquid* gasoline. How many moles of octane vapour are present in this tank at SATP?

* SATP = 25°C & 100 KPa

P = 100 KPa
V = 70.0 L
n = ?
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 25°C = 298 K

$PV = nRT$
$100(70.0) = n(8.314)(298)$
n = 2.83 mol

4. A 10.0 L sample of helium gas contains 0.650 mol and is at 105 kPa. What is the temperature in °C?

P = 105 KPa
V = 10.0 L
n = 0.650 mol
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = ?

$PV = nRT$
$105(10.0) = (0.650)(8.314)T$
T = 194.2969 K
-78.7°C

5. Calculate the mass of neon gas in a neon sign with a volume of 50 L at 10°C and 3.1 kPa.

P = 3.1 KPa
V = 50 L
n = ?
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 10°C = 283 K

$PV = nRT$
$(3.1)(50) = n(8.314)(283)$
n = 0.06588 mol

$\frac{20.18 g}{1 mol} = \frac{x g}{0.06588 mol}$
x = 1.3 g

6. Calculate the volume of 8.4 g of nitrogen gas at 200°C and 130 kPa.

P = 130 KPa
V = ?
n = 0.29978 mol
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 200°C = 473K

$\frac{28.02g}{1 mol} = \frac{8.4g}{X mol}$

X = 0.29978 molN_2

PV = nRT

(130)(V) = (0.29978)(8.314)(473)

V = 9.1L

7. Hydrogen gas is generated by the decomposition of water to fill a 1.1 kL weather balloon at 20°C and 100 kPa. What is the mass of hydrogen gas in the balloon?

P = 100 KPa
V = 1.1 KL = 1100 L
n = ?
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 293K

PV = nRT

(100)(1100) = n(8.314)(293)

n = 45.1559 mol

$\frac{2.02g}{1 mol} = \frac{X g}{45.1559 mol}$

X = 91g

8. What is the temperature of 45.3 g of ammonia gas if it occupies 64.2 L at 150 kPa?

P = 150 KPa
V = 64.2L
n = 2.6584 mol
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = ?

$\frac{17.04g}{1 mol} = \frac{45.3g}{X mol}$

X = 2.6584 mol

PV = nRT

(150)(64.2) = (2.65845)(8.314)T

T = 435.7K

163°C or 436K

9. A student is conducting an experiment to determine the molar mass of a gas. She has a 2.44 g sample of a gas in a volume of 15.0 L. The pressure is 100 kPa and the temperature is 23.0 °C. Calculate the molar mass of the gas and determine the identity of the gas she was using.

P = 100 KPa
V = 15.0L
n =
R = 8.314 $\frac{KPa \cdot L}{mol \cdot K}$
T = 23°C = 296K

PV = nRT

(100)(15) = n(8.314)(296)

n = 0.609522

$\frac{2.44g}{0.609522 mol} = \frac{X g}{1 mol}$

X = 4.003g/mol

4.00g/mol - He gas

Calculation of the Universal Gas Constant

Problem:
What is the experimental value for the universal gas constant (R).

Experimental Design:
The mass of an empty 250.0 mL syringe was measured and recorded. The syringe was then filled with **helium gas** and the mass was measured and recorded again. The pressure and temperature in the room were measured and recorded. This process was repeated three times.

Data Table:

Trial	Pressure (kPa)	Volume (L)	Mass of Syringe (g)	Mass of Syringe + gas (g)	Temperature (°C)
1	99.80	0.2500	8.350	8.391 mass gas = 0.041	22.00°C 295K
2	102.5	0.2500	8.350	8.392 mass gas = 0.042	19.05°C 292.05
3	101.7	0.2500	8.350	8.392 mass gas = 0.042	18.45°C 291.45

Analysis:

1. Calculate the universal gas constant for each of the 3 trials. Show all of your work…formulas, substitution, units, final answer.
2. Calculate the average value of the universal gas constant for this data set.
3. Calculate the % error, again showing all work, for the universal gas constant. The measured value is what you calculated from your lab data. The accepted value is the Data Sheet value.

$$\% \text{ error} = \frac{\text{measured value} - \text{accepted value}}{\text{accepted value}} \times 100$$

① Trial 1

$\frac{4.00g}{1 mol} = \frac{0.041}{x}$, $x = 0.01025$

$PV = nRT$

$(99.80)(0.2500) = (0.01025)R(295)$

$R = 8.251 \frac{kPa \cdot L}{mol \cdot K}$

Trial 2

$\frac{4.00g}{1 mol} = \frac{0.042}{x}$, 0.0105 mol

$PV = nRT$

$(102.5)(0.2500) = 0.0105(R)(292.05)$

$R = 8.356 \frac{kPa \cdot L}{mol \cdot K}$

Trial 3

$PV = nRT$

$(101.7)(0.2500) = (0.0105)R(291.4$

$R = 8.308 \frac{kPa \cdot L}{mol \cdot K}$

② $\text{Average} = \frac{8.251 + 8.356 + 8.308}{3} = 8.305 \frac{kPa \cdot L}{mol \cdot K}$

③ $\%\text{error} = \frac{8.305 - 8.314}{8.314} \times 100$

$= |0.1083\%|$