The Gas Laws

Rigid & Flexible Containers

Walls: rigid
Volume: constant
Rupture when internal pressure exceeds container strength
Example: compressed gas cylinder

Walls: flexible
Volume: constant if internal & surroundings pressures equal
Volume: changes if internal & surroundings pressures unequal
Rupture when internal pressure exceeds container strength
Examples: balloon, internal air spaces (lungs, ears, sinus, gut)

Joseph LouisGuy-Lussac

Pressure Temperature Relationship-1809

French chemist; student of Jacques Charles

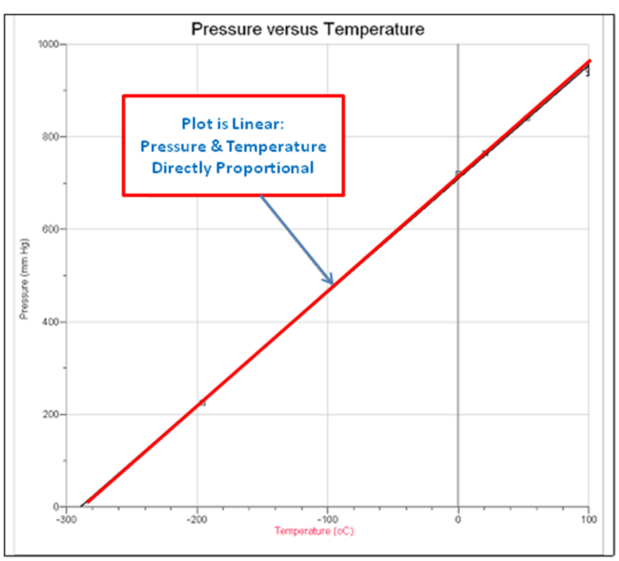
His “Law” (pressure-temp relationship) sometimes referred to as Charles’s Law Or Charles’s Law #2. But, Guy-Lussac was first to develop the apparatus to allow observations documenting the relationship

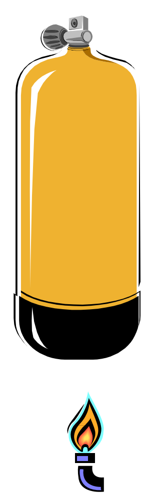
Guy-Lussac’s Law

Heat energy increases molecular motion.
Since volume of cylinder cannot increase, the pressure elevates.

At constant *volume, in a rigid container,* pressure is directly proportional to the absolute temperature

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$





A sample of oxygen has a pressure of 1420 mm Hg at T = 75 °C. What is the pressure of this gas sample if T = 19° C?

	Pressure (torr)*	**Volume**	**Temperature (°C)**		**Temperature (K)**
Initial	1420	constant	75	+ 273	348
Final	?	constant	19	+ 273	292

Volume constant, use Guy-Lussac's Law

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Solving for P_2:

$$\frac{P_1 T_2}{T_1} = P_2$$

$$\frac{(1420 \text{ torr})(292 \text{ K})}{348 \text{ K}} = P_2$$

P_2 = 1191.49 torr ➔ 1190 torr

Calculate the pressure a gas will exert at 65 °C if the gas has a pressure of 830 torr at 52 °C.

	Pressure (torr)	**Volume**	**Temperature (°C)**		**Temperature (K)**
Initial	830	constant	52	+ 273	325
Final	?	constant	65	+ 273	338

Volume constant, use Guy-Lussac's Law

$$\frac{830}{T_1} = \frac{P_2}{T_2}$$

Solving for P_2:

$$\frac{P_1 T_2}{T_1} = P_2$$ ➔

$$\frac{(830 \text{ torr})(338 \text{ K})}{325 \text{ K}} = P_2$$

P_2 = 863.2 torr ➔ 863 torr

A sample of nitrogen has a pressure of 1420. torr at a temperature of 75 °C. What is the ° C temperature of this gas if the pressure is lowered to 258 torr?

	Pressure (torr)	Volume	Temperature (°C)		Temperature (K)
Initial	1420	constant	75	+ 273	348
Final	258	constant	?	+ 273	?

Volume constant, use Guy-Lussac's Law

$$\frac{1420 \text{ torr}}{348 \text{ K}} = \frac{258 \text{ torr}}{T_2} \qquad \frac{(258 \text{ torr})(348 \text{ K})}{(1420 \text{ torr})} = T_2$$

$$T_2 = 63.2262 \text{ K} \rightarrow T_2 = 63.2 \text{ K}$$

$$T_2 = 63.2 \text{ K} - 273 = -210\ ^\circ\text{C}$$

Jacques Charles

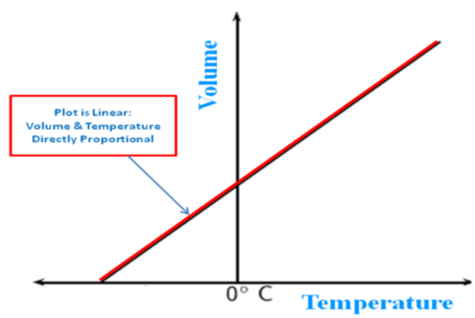
Volume Temperature Relationship-1787

Scientific Advisor to the Montgolfier brothers
Redesigned the way hot-air balloons were built.
He invented the valve line & wicker basket passenger compartment
He also suggested the use of hydrogen instead of plain "hot-air"

Heat energy increases molecular motion.

At constant *pressure,* in a flexible container
the volume is directly proportional to the absolute temperature

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$



A sample of oxygen occupies a volume of 1240 mL at T = 45° C. What is the volume of this gas sample if T = 85° C?

	Pressure	Volume (mL)	Temperature (°C)		Temperature (K)
Initial	constant	1240	45	+ 273	318
Final	constant	?	85	+ 273	358

Pressure constant, use Charles's Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Solving for V_2:

$$\frac{V_1 T_2}{T_1} = V_2$$

$$\frac{(1240\text{ mL})(358\text{ K})}{318\text{ K}} = V_2$$

V_2 = 1395.97 mL ➔ 1400 mL

Calculate the volume a gas will occupy at 15 °C if the gas has a volume of 830 mL at 42 °C.

	Pressure	Volume (mL)	Temperature (°C)		Temperature (K)
Initial	constant	830	42	+ 273	315
Final	constant	?	15	+ 273	288

Pressure Constant; Use Charles' Law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \rightarrow \frac{V_1 T_2}{T_1} = V_2$$

$$\frac{(830\text{ mL})(288)\text{ K})}{315\text{ K}} = V_2$$

V_2 = 758.857 mL ➔ 759 mL

Calculate the final temperature of a gas at 39 °C whose volume changes from 348 ml to 657 mL. The pressure remains constant.

	Pressure	Volume (mL)	Temperature (°C)		Temperature (K)
Initial	constant	348	39	+ 273	312
Final	constant	657	?	+ 273	?

Need absolute temperatures

$T_1 = 39 + 273 = 312$ K

Pressure Constant; Use Charles' Law

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$ ➔ $\frac{V_2 T_1}{V_1} = T_2$

$\frac{(657 \text{ mL})(312 \text{ K})}{348 \text{ mL}} = T_2$

$T_2 = 589.038$ K ➔ 589 K

$T_2 = 589 - 273 = 316$ °C

Robert Boyle

Irish Alchemist, Father of modern chemistry

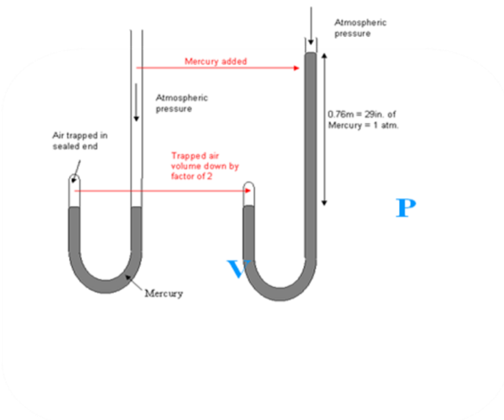
1660

New Experiments: Phsico-Mechanical Touching the spring of air and their effects

1661

The Sceptical Chymst (air, earth, fire, water were not elements)
A Founder of English Royal Society

Boyles's Law Apparatus



Measure height mercury (P)
Measure Volume (V)

$P_1V_1 = k$
$P_2V_2 = k$
$P_3V_3 = k$

Set Equalities Equal to each other

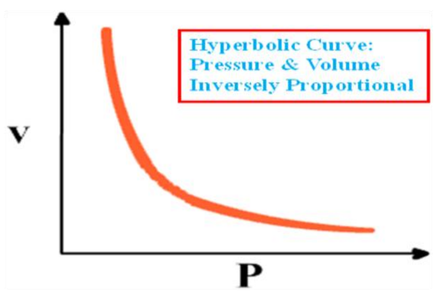
$P_1V_1 = k = P_2V_2$

$P_1V_1 = P_2V_2$

Boyle's Law

At constant *temperature*, the volume of a flexible container is inversely proportional to the absolute pressure

$$p_1 v_1 = p_2 v_2$$



At 723 mm Hg a gas has a volume of 294 mL. What is the new volume of this gas if the pressure is changed to 585 mm Hg?

	Pressure (mm Hg)	Volume (mL)	Temperature (°C)	Temperature (K)
Initial	**723**	**294**	**constant**	**constant**
Final	**585**	**?**	**constant**	**constant**

Temperature constant, use Boyle's Law: $p_1 v_1 = p_2 v_2$

(723 torr) (294 mL) = (585 torr) v_2

$\frac{(723 \text{ torr})(294 \text{ mL})}{(585 \text{ torr})} = v_2$

v_2 = 363.354 mL → 363 mL

Calculate the new volume of a 4.87 L gas sample if its pressure is changed from 0.68 atm to 2.4 atm.

	Pressure (tatm)	**Volume (L)**	**Temperature (^oC)**
Initial	0.68	4.87	Constant
Final	2.4	?	Constant

Temperature constant, use Boyle's Law

$p_1 v_1 = p_2 v_2$

(0.68 atm) (4.87 L) = (2.4 atm) V_2

$\frac{(0.68 \text{ atm})(4.87 \text{ L})}{(2.4 \text{ atm})} = v_2$ $\qquad$ v_2 = 1.37983 L ➔ 1.4 L

At 723 torr a gas has a volume of 294 mL. What is the new pressure of this gas if the volume is changed to 1256 mL?

	Pressure (torr)	**Volume (mL)**	**Temperature (^oC)**	**Temperature (K)**
Initial	723	294	constant	constant
Final	?	1256	constant	constant

Temperature constant, use Boyle's Law

(723 torr) (294 mL) = (1256 mL) P_2

$\frac{(723 \text{ torr})(294 \text{ mL})}{(1256 \text{ mL})} = P_2$

P_2 = 169.237 ➔ 169 torr

General Gas Law

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

If P constant: $\frac{v_1}{t_1} = \frac{v_2}{t_2}$ **Charles**

If V constant: $\frac{p_1}{t_1} = \frac{p_2}{t_2}$ **Guy-Lussac**

If T constant: $p_1v_1 = p_2v_2$ **Boyle**

A sample of neon with a volume of 825 mL at a temperature of 37 °C and a pressure of 600. torr is heated to a temperature of 68 °C and a pressure of 940 mm Hg. What is the new volume of the gas?

	Pressure (torr)	**Volume (mL)**	**Temperature (^oC)**		**Temperature (K)**
Initial	600	825	37	+ 273	310
Final	940	?	68	+ 273	341

Pressure, Volume & Temperature change, use General Gas Law

$$\frac{p_1 v_1}{t_1} = \frac{p_2 v_2}{t_2}$$

$$\frac{(600 \text{ torr})(825 \text{ mL})}{310 \text{ K}} = \frac{(940 \text{ torr})\, v_2}{341 \text{ K}}$$

$$V2 = \frac{(600 \text{ torr})(825 \text{ mL})(341 \text{ K})}{(310 \text{ K})(940 \text{ torr})}$$

V_2 = 579.255 mL ➔ 579 mL

A gas sample with a volume of 4.37 L at a temperature of 58 °C at 725 torr is cooled to a temperature of 22 °C and a pressure of 615 mm Hg. What is the new volume of the gas?

	Pressure (torr)	**Volume (L)**	**Temperature (^oC)**		**Temperature (K)**
Initial	725	4.37	58	+ 273	331
Final	615	?	22	+ 273	295

Pressure, Volume & Temperature change, use General Gas Law

$$\frac{p_1 v_1}{t_1} = \frac{p_2 v_2}{t_2}$$

$$\frac{(725 \text{ torr})(4.37 \text{ L})}{331 \text{ K}} = \frac{(615 \text{ torr})\, v_2}{295 \text{ K}}$$

$$\frac{(725 \text{ torr})(4.37 \text{ L})(295)}{(331 \text{ K})(615 \text{ torr})} = v_2$$

V_2 = 4.59133 L ➔ 4.59 L

A sample of nitrogen with a volume of 14.7 L at a temperature of 95 °C and a pressure of 485 torr is cooled to a temperature of 35 °C and a pressure of 715 mm Hg. What is the new volume of the gas?

	Pressure (torr)	**Volume (L)**	**Temperature (^oC)**		**Temperature (K)**
Initial	485	14.7	95	+ 273	368
Final	760	?	0	+ 273	273

Pressure, Volume & Temperature change, use General Gas Law

$$\frac{p_1 v_1}{t_1} = \frac{p_2 v_2}{t_2}$$

$$\frac{(485 \text{ torr})(14.7 \text{ L})}{368 \text{ K}} = \frac{(715 \text{ torr})\ v_2}{308 \text{ K}}$$

$$\frac{(485 \text{ torr})(14.7 \text{ L})(308 \text{ K})}{(368 \text{ K})(715 \text{ torr})} = v_2$$

V_2 = 8.344557 L ➔ 8.35 L

A sample of neon at STP has a volume of 286 L. What is the pressure in atmospheres if the temperature is changed to 95 °C at a new volume of 26.5 L?

	Pressure (ata)*	**Volume (L)**	**Temperature (^oC)**		**Temperature (K)**
Initial	1.00	286	0	+ 273	273
Final	?	26.5	95	+ 273	368

Pressure, Volume & Temperature change, use General Gas Law

$$\frac{p_1 v_1}{t_1} = \frac{p_2 v_2}{t_2}$$

$$\frac{(1.00 \text{ ata})(286 \text{ L})}{273 \text{ K}} = \frac{P_2(26.5 \text{ L})}{368 \text{ K}} \rightarrow \frac{(1.00 \text{ ata})(286 \text{ L})(368 \text{ K})}{(273 \text{ K})(26.5 \text{ L})} = P_2$$

P_2 = 14.5481 ata ➔ 14.5 ata

A sample of xenon with a volume of 825 mL at a temperature of 37 °C and a pressure of 600. torr is changed to a pressure of 940. mm Hg at a volume of 628 mL. What is the temperature in ^{o}C of the gas?

	Pressure (torr)	**Volume (mL)**	**Temperature (^{o}C)**		**Temperature (K)**
Initial	600	825	37	+ 273	310
Final	940	628	?	+ 273	?

Pressure, Volume & Temperature change, use General Gas Law

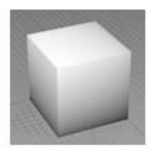
$$\frac{p_1 v_1}{t_1} = \frac{p_2 v_2}{t_2}$$

$$\frac{(600 \text{ torr})(825 \text{ mL})}{310 \text{ K}} = \frac{(940 \text{ torr})(628 \text{ mL})}{T_2} \Rightarrow \frac{(940 \text{ torr})(628\text{mL})(310 \text{ K})}{(600 \text{ torr})(825 \text{ mL})} = T_2$$

$T_2 =$ 369.695 K ➔ 370 K

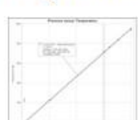
$T_2 =$ 370 K – 273 = 97 ^{o}C

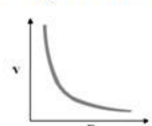
Proportional Thinking



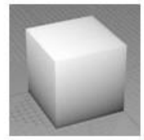
$$\frac{p\,v}{t} = k$$

If P constant:	**If V constant:**	**If T constant:**
$\frac{v}{t} = k$	$\frac{p}{t} = k$	$pv = k$
Charles' Law Direct Proportion	**Guy-Lussac's Law Direct Proportion**	**Boyle's Law Inverse Proportion**





Proportional Thinking



$$\frac{p\,v}{t} = k$$

Variables change to keep k constant

If P constant:

$$\frac{\uparrow v}{\uparrow t} = k$$

v and t change (increase or decrease) in same direction

If V constant:

$$\frac{\uparrow p}{\uparrow t} = k$$

p and t change (increase or decrease) in same direction

If T constant:

$$\underset{\uparrow}{p}\,\underset{\downarrow}{v} = k$$

p and v change (increase or decrease) in opposite direction

Proportional Thinking: Word problems

At constant volume, if temperature decreases, pressure **decreases**

$$\frac{\downarrow p}{\downarrow t} = k$$

At constant pressure, if temperature increases, volume **increases**

$$\frac{\uparrow v}{\uparrow t} = k$$

At constant temperature, if pressure increases, volume **decreases**

$$\underset{\uparrow}{p}\,\underset{\downarrow}{v} = k$$

Assignment

Continue Taking Unit 8 Practice Test
Blackboard only records highest score
Take until multiple 100's have been scored (questions are variable)
(Gives sense of test exam format and content)

The Practice Quiz is very similar to the Unit Exam
Success on Unit exam is directly related to practice exam experience