# *Gases*

*Dr. Ron Rusay*



What makes TNT "explosive" versus sucrose or lactose?

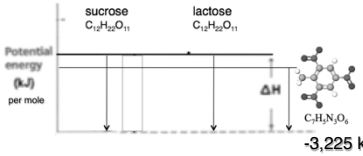
TNT
Trinitrotoluene

-5340 kJ /mol $_{sucrose}$ -5340 kJ /mol $_{lactose}$

glucose + fructose

glucose + galatose

sucrose $C_{12}H_{22}O_{11}$ lactose $C_{12}H_{22}O_{11}$

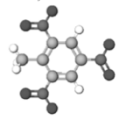



-3,225 kJ/mol

What makes TNT "explosive" versus sucrose or lactose?

TNT
Trinitrotoluene

https://www.youtube.com/watch?v=go4NO8v7Goc

_4_  + _21_ 

$4\ C_7H_5N_3O_6$ + $21\ O_2(g)$

↓

$6\ N_2(g) + 10\ H_2O\ (g) + 28\ CO_2\ (g)$ + energy

$2\ C_{12}H_{22}O_{12}\ (s) + 23\ O_2(g) \rightarrow 24\ CO_2(g) + 22\ H_2O(g)$

***Kinetics (speed of reaction) & Gases Produced***

What is the difference in the total bonds in reactants & products?

TNT

The energy produced from exploding TNT comes from _____. chemical bonds. *

- ○ forming
- ○ breaking
- ○ both breaking and forming bonds with no net difference in energy of the
- ☒ both breaking and forming bonds with a net release of energy from the difference of the
- ○ both breaking and forming bonds with a net gain of energy from the difference of the

Heat of Reaction = - 3,225 kJ/mol

***Exothermic: the net effect of breaking & making bonds releases energy.***

What is the difference in the total bonds in reactants & products?

The energy produced from digesting food comes from _____ chemical bonds. *

- ○ forming
- ○ breaking
- ○ both breaking and forming bonds with no net difference in energy of the
- ○ both breaking and forming bonds with a net release of energy from the difference of the
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What is the difference in the total bonds in reactants & products?

The energy produced from photosynthesis comes from_____. chemical bonds. *

- ○ forming
- ○ breaking
- ○ both breaking and forming bonds with no net difference in energy of the
- ☒ both breaking and forming bonds with a net release of energy from the difference of the
- ○ both breaking and forming bonds with a net gain of energy from the difference of the

Heat of Reaction = (+) kJ/mol

***Endothermic: the net effect of breaking & making bonds absorbs energy.***

# Gases

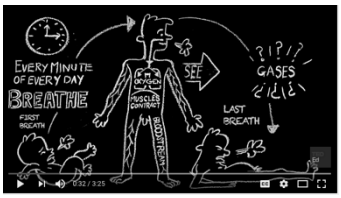
*Dr. Ron Rusay*

TED: Gas Laws
https://www.youtube.com/watch?v=BY9VGS2eXas



# Gases

*Introduction (0:00 - 1:06)*




https://www.youtube.com/watch?v=EHxdVtygP1g&t=88s

# Gases

TED: Gas Properties
https://www.youtube.com/watch?v=EHxdVtygP1g&t=88s

- *Uniformly fill any container.*
- *Exert pressure on its surroundings.*
- *Mix completely with other gases.*

# Gases:
## *Pressure, Mass, Volume, Temperature*

http://chemconnections.org/general/movies/bicycle-gases.MOV

# Total Pressure:
## *Sum of the Partial Pressures*

- *For a mixture of gases, the total pressure is the sum of the pressures of each gas in the mixture.*

$P_{Total} = P_1 + P_2 + P_3 + \ldots$

$P_{Total} \propto n_{Total}$

$n_{Total} = n_1 + n_2 + n_3 + \ldots$

# Barometric Pressure:
## *Sum of the Partial Pressures*

- *For a mixture of gases, the total pressure is the sum of the pressures of each gas in the mixture.*
  - $P_{Barometric} = P_1 + P_2 + P_3 + \ldots$

$P_{Barometric} \propto n$

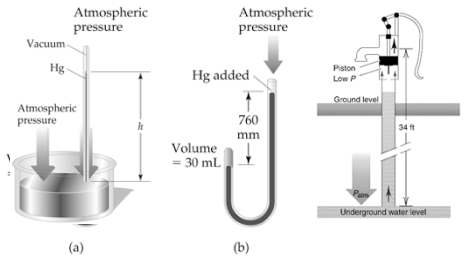
$n_{Barometric} = n_1 + n_2 + n_3 + \ldots$

**Atmospheric Composition Near Sea Level (Dry Air)***

| Component | Mole Fraction |
|---|---|
| $N_2$ | 0.78084 |
| $O_2$ | 0.20948 |
| Ar | 0.00934 |
| $CO_2$ | 0.000345 |
| Ne | 0.00001818 |
| He | 0.00000524 |
| $CH_4$ | 0.0000168 |
| Kr | 0.00000114 |
| $H_2$ | 0.0000005 |
| NO | 0.0000005 |
| Xe | 0.000000087 |

*The atmosphere contains various amounts of water vapor depending on conditions.

## Toricellian Barometer

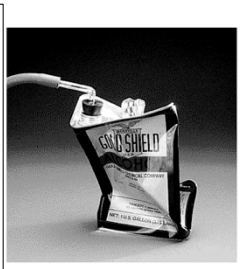




*An empty one gallon can is hooked to a vacuum pump.*

*What do you expect to happen?*

*Explain why the can collapsed.*




TED: Gas Laws
https://www.youtube.com/watch?v=BY9VGS2eXas

## *Boyle's Law**

- *Pressure × Volume = Constant (T = constant)*
  - $P_1V_1 = P_2V_2$ *(T = constant)*
  - $V \propto 1/P$ *(T = constant)*
- *(*Holds precisely only at very low pressures.)*

$P_1V_1 = P_2V_2$
$P\uparrow \quad V\downarrow$

## *Ideal Gases*

*Real vs. "Ideal"*

**PV = n RT**

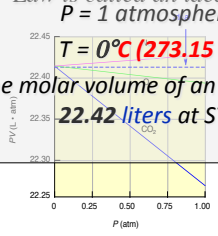
*n = 1 mole of a gas (STP)*

*P = 1 atmosphere*

*T = 0°C (273.15 K)*

*The molar volume of an ideal gas is* ***22.42*** *liters at STP*

*Definition: A gas that strictly obeys Boyle's Law is called an ideal gas.*

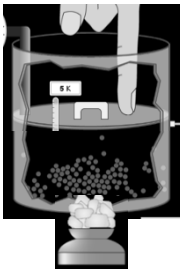



## *QUESTION*

*If a container with neon gas is made smaller, while keeping the temperature constant, what happens to the pressure & volume of neon gas?*

**$Ne_{(g)}$**

A. *The volume increases & pressure increases.*
B. *The volume increases & pressure decreases.*
C. *The volume decreases & pressure decreases.*
D. *The volume decreases & pressure jncreases.*



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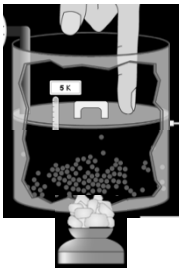
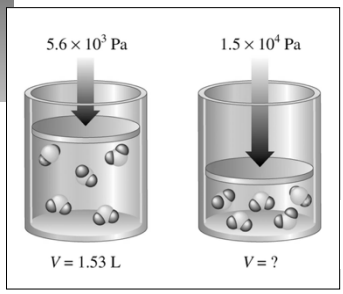


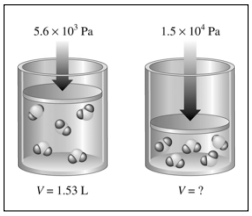
## *QUESTION*




**A) 4.0 L**
**B) 0.57 L**
**C) 5.7 L**
**D) 0.4 L**

$P_1 V_1 = P_2 V_2$
$P\uparrow \quad V\downarrow$

## *ANSWER*




**A) 4.0 L**
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**C) 5.7 L**
**D) 0.4 L**

$P_1 V_1 = P_2 V_2$
$P\uparrow \quad V\downarrow$

$V_2 = P_1 V_1 / P_2$

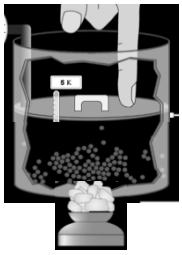
## Question

### *Gas ⇌ Liquid Equilibrium*

*What happens when a container is made smaller with neon gas and neon liquid, while keeping the temperature constant?*
***(The system minimizes any increase in pressure & follows Boyle's Law.)***

**$Ne_{(g)} \rightleftharpoons Ne_{(l)}$**

A. *The system will shift to the right producing more liquid.*
B. *The system will shift to the left producing more gas.*
C. *This system would not affected.*



## Answer

### *Gas ⇌ Liquid Equilibrium*

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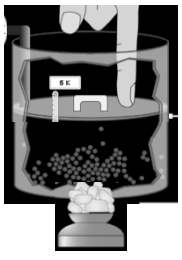
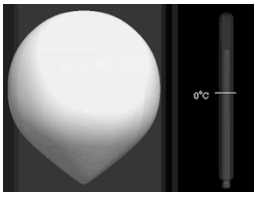


## *Temperature & Volume*




http://chemconnections.org/general/movies/V-and-T.MOV

http://chemconnections.org/general/movies/Vol-T-liqN2HMVID10.MOV

## *Temperature & Volume*

$N_{2\,(liq)}$ b.p.= –196 °C (77 K; –321 °F)
A cryogenic fluid which can cause rapid freezing on contact with living tissue, which may lead to frostbite.

## *Charles's Law*

*The volume of a gas is directly proportional to temperature, and extrapolates to zero at zero Kelvin.*

$\delta \quad V = \alpha T \quad (P = \text{constant})$

$\alpha$ = *a proportionality constant*

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad (P = \text{constant})$$

$V_1 / T_1 = V_2 / T_2$
$V\uparrow \quad T\uparrow$

# *QUESTION*

If a 10.0 L sample of an ideal gas at 300K suddenly had its temperature doubled without changing its pressure, what would happen to its volume?

A) The volume would decrease to 2.0 L.
B) The volume would triple.
C) The volume would not change since the pressure remains constant.
D) The new volume would be 20.0L.

$V_1 / T_1 = V_2 / T_2$
$V\uparrow \quad T\uparrow$

$V_2 = T_2 V_1 / T_1$

# *Answer*

If a 10.0 L sample of an ideal gas at 300K suddenly had its temperature doubled without changing its pressure, what would happen to its volume?

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$V\uparrow \quad T\uparrow$

$V_2 = T_2 V_1 / T_1$

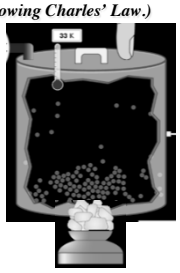
## Question

### *Gas ⇌ Liquid Equilibrium*

*What happens when a container with neon gas and neon liquid is cooled, while keeping the pressure constant?* ***(The system responds by following Charles' Law.)***

$Ne_{(g)} \rightleftharpoons Ne_{(l)}$

A. *The system will shift to the right producing more liquid.*
B. *The system will shift to the left producing more gas.*
C. *This system would not be affected.*




## Answer

### *Gas ⇌ Liquid Equilibrium*

*What happens when a container with neon gas and neon liquid is cooled, while keeping the pressure constant?* ***(The system responds to follow Charles' Law.)***

$Ne_{(g)} \rightleftharpoons Ne_{(l)}$

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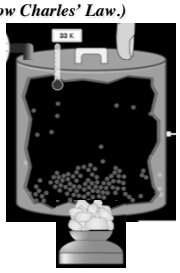
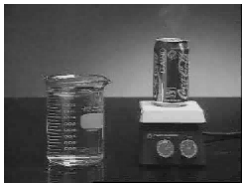
B. *The system will shift to the left producing more gas.*
C. *This system would not be affected.*



## *Pressure, Volume & Temperature*



http://chemconnections.org/general/movies/Press-Vol-Temp-can.MOV

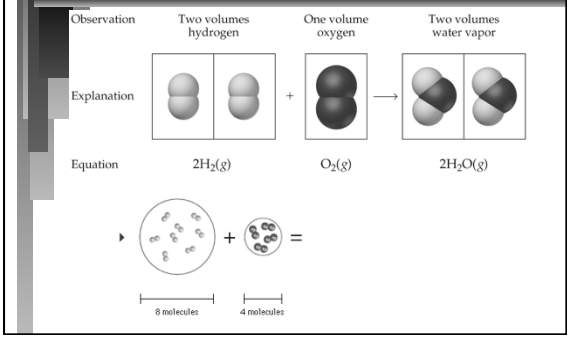
## *Avogadro's Law*

- *For a gas at constant temperature and pressure, the volume is directly proportional to the number of moles of gas (at low pressures).*
- $V = \alpha n$
- $\alpha$ = *proportionality constant*
- *V = volume of the gas*
- *n = number of moles of gas*

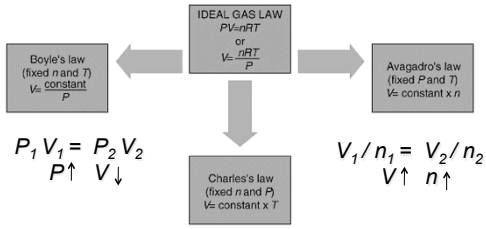
$$V_1 / n_1 = V_2 / n_2$$
$$V\uparrow \quad n\uparrow$$

http://chemconnections.org/general/movies/Gases-n-vs-V.mov

## *Volume vs. n (moles of a gas)*



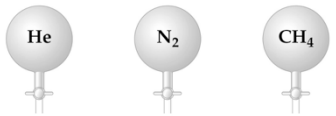

Isobaric process: pressure constant
Isochoric process: volume constant
Isothermal process: temperature constant




$$P_1 V_1 = P_2 V_2$$
$$P\uparrow \quad V\downarrow$$

$$V_1 / n_1 = V_2 / n_2$$
$$V\uparrow \quad n\uparrow$$

$$V_1 / T_1 = V_2 / T_2$$
$$V\uparrow \quad T\uparrow$$

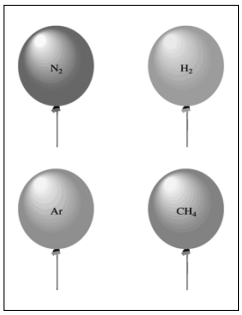



| | He | $N_2$ | $CH_4$ |
|---|---|---|---|
| Volume | 22.4 L | 22.4 L | 22.4 L |
| Pressure | 1 atm | 1 atm | 1 atm |
| Temperature | 0°C | 0°C | 0°C |
| Mass of gas | 4.00 g | 28.0 g | 16.0 g |
| Number of gas molecules | $6.02 \times 10^{23}$ | $6.02 \times 10^{23}$ | $6.02 \times 10^{23}$ |

# *QUESTION*

Each of the balloons hold 1.0 L of different gases. All four are at 25°C and each contains the same number of molecules. Of the following which would also have to <u>be the same</u> for each balloon? (obviously not their color)

A) Their density
B) Their mass
C) Their atomic numbers
D) Their pressure



# *ANSWER*

D)
The temperature, number of moles, volume and **pressure** are all interrelated for a sample of any trapped gas.

# *QUESTION*

Which sequence represents the gases in order of increasing density at STP?

**A) Fluorine < Carbon monoxide < Chlorine < Argon**

**B) Carbon monoxide < Fluorine < Argon < Chlorine**

**C) Argon < Carbon monoxide < Chlorine < Fluorine**

**D) Fluorine < Chlorine < Carbon monoxide < Argon**

NOTE the mass relationship
in the previous question.

# *ANSWER*

Which sequence represents the gases in order of increasing density at STP?

**A) Fluorine < Carbon monoxide < Chlorine < Argon**

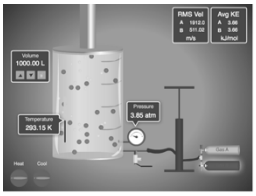
**B) Carbon monoxide < Fluorine < Argon < Chlorine**

**C) Argon < Carbon monoxide < Chlorine < Fluorine**

**D) Fluorine < Chlorine < Carbon monoxide < Argon**

**Increasing density: increasing Molar Mass**
Carbon monoxide < Fluorine < Argon < Chlorine

*Ideal Gas Law Simulator*




http://ch301.cm.utexas.edu/simulations/gas-laws/GasLawSimulator.swf

# *QUESTION*

If a 10.0 L sample of a gas at 25°C suddenly had its volume doubled, without changing its temperature what would happen to its pressure? What could be done to keep the pressure constant without changing the temperature?

A. The pressure would double; nothing else could be done to prevent this.
B. The pressure would double; the moles of gas could be doubled.
C. The pressure would decrease by a factor of two; the moles of gas could be halved.
D. The pressure would decrease by a factor of two; the moles could be doubled.

# *ANSWER*

D) describes two opposing changes. When the volume increases, the pressure of a trapped gas will decrease (at constant temperature and constant moles of gas). However, if the pressure drops, more collisions could be restored by adding more particles of gas in the same ratio as the pressure decline.

Steam engines require water to be added to replace the steam lost in doing work.

## *Gases & Airbags*

*Use of Chemical Reactions and Physical Properties*

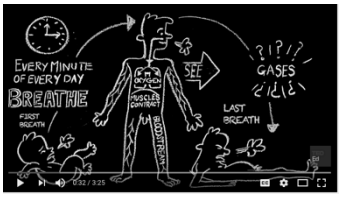

http://chemconnections.org/public_html/general/movies/airbags.MOV

## *Molecular Motion & Energy*

*Gases & the Meaning of Temperature (1:06 – 3:25)*

*Temperature (Kelvin) is an index of the random motions of gas particles (higher T means greater motion.)*

$$(\mathrm{KE})_{\mathrm{avg}} = \frac{3}{2}RT$$




https://www.youtube.com/watch?v=EHxdVtygP1g&t=88s