


Slide 1

Clicker Question

Iron can be reacted with nitrogen to yield iron nitride in the reaction:
 $3 \text{Fe (s)} + \text{N}_2\text{(g)} \rightarrow \text{Fe}_3\text{N}_2\text{(s)}$

10.0 g Fe and 2.00 g N_2 are placed in a calorimeter at 25.0°C and the reaction triggered. The heat capacity of the calorimeter (INCLUDING WATER) is $14.7 \text{ kJ/}^\circ\text{C}$. If the final temperature of the calorimeter is 21.2°C , what is the ΔH of the reaction?


A. 55.9 kJ/mol
B. -55.9 kJ/mol
C. $782. \text{ kJ/mol}$
D. 936 kJ/mol
E. -936 kJ/mol



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Ideal Gas Law

Another fluid




Slide 3

Chemistry is all about...

MOLES! MOLES! MOLES!

(Nice job – class dismissed.)



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Moles is central...

...but to have a middle, you need a beginning and an end.

Our most common calculation:

Grams to moles, moles to moles, moles to grams


This works when "weighing" is appropriate.



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For solutions...???

Molarity to moles, moles to moles, moles to molarity




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It's all about what's easiest:

If you have a pure solid or a pure liquid, just throw it on a balance!

If you have a solution, throw it in a graduated cylinder.


If you have a gas...you could mass it, but they are very light!



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Gas laws

Getting MOLES! MOLES! MOLES! if your reactants and products are gases.




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Solids, liquids and gases

There are 3 main states of matter:

- Solids
- Liquids
- Gases

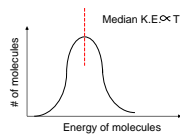
Each of the 3 have properties that are unique, but there is a gradual transition from one state of matter to the other.



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Kinetic Model of Matter

Temperature, is a reflection of the role of molecular motions in systems



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Kinetic Model of Matter




The difference between the different states of matter can also be related to the motions of the molecules:

- Solids – very little motion
- Liquids – free movement of molecules among each other
- Gases – free movement in mostly empty space

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Kinetic Model of Matter




This difference in motion is a function of the relationship between the kinetic energy of the molecules and the forces of attraction of the molecules.

- Solids – not enough KE to break free of neighbors.
- Liquids – enough KE to be free, but still attracted to the girl next door.
- Gases – so much KE that you can't slow down to greet the neighbors.

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Solids are different – more different



Liquids and gases are distinctly different, but they are much more like each other than either is like a solid.

Liquids and gases are both considered **fluids**.

Fluids flow!


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Pressure

Fluids also have a new property we haven't discussed – **Pressure**.

Do you know what pressure is?

Pressure = $\frac{\text{Force}}{\text{Area}}$




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Molecular Dynamics Picture

On the molecular scale, what is pressure?
Where does the "force" come from?

It is the force of the molecules bumping into the walls of the container holding the gas.




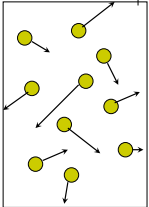
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A picture paints a thousand words...

The molecules of a gas are in constant motion.

The molecules have random directions and a distribution of energies (think T).

The molecules collide with each other and the barriers of the vessel.

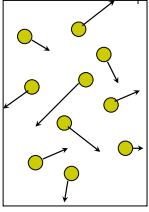


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A picture paints a thousand words...

Every collision causes an exchange of energy.

The "average KE" (T), however, stays the same.




The diagram shows a rectangular box containing several yellow circles representing particles. Each particle has a black arrow indicating its direction of motion. Some particles are in the process of colliding, with arrows pointing towards each other. After collisions, the arrows change direction, illustrating the exchange of energy between particles. A small decorative graphic of colored dots is located in the top right corner of the slide content area.

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Other properties of gases...

Besides pressure, what are the other physical properties of gases (or any matter):

- Mass
- Density
- Volume (length, width, height)
- Temperature
- # of moles (how many particles)
- Color, texture




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Gases


Why do NASCAR teams under-inflate (low pressure) their tires in the pits?

Because the tires get very hot at 200 m.p.h. and the Pressure increases with Temperature!

$P \propto T$




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<http://www.youtube.com/watch?v=WLP0BL681Hs&feature=related>

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Gases

Why does a balloon inflate when you blow into it?

Because the Volume is proportional to how much stuff (moles) you put into it!

$V \propto n$ (Avogadro's Law)

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Gases

What happens when you put a balloon in the freezer?

It shrinks! Volume is proportional to the Temperature.

$V \propto T$ (Charles' Law)


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Gases

If you have a cylinder of helium, why is it that you can inflate a balloon that is much bigger than the cylinder?


Because the Volume is INVERSELY proportional to the Pressure!

$P \propto 1/V$ (Boyle's Law)



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<http://www.youtube.com/watch?v=Mytv0wlZK8>




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The 1st Clicker Question!!!

If I have Helium under 12 atm of pressure in a 10 L cylinder, how big would the balloon be at atmospheric pressure (1 atm)? (Assume all other conditions remain constant.)

A. 1.2 L
B. 120 L
C. 0.833 L
D. 83.3 L



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Since P is proportional to $1/V$, that means

$PV = \text{constant}$

What constant? More on that later, but it is constant.

$P_1V_1 = P_2V_2$
(12 atm) (10 L) = 1 atm * V_2
 $V_2 = 120 \text{ L!}$


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What did I mean by "Assume all other conditions remain constant"?

Any condition that affects either the P or the V of the gas!

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Relevant Gas variables

From my earlier examples:

$P \propto T$
 $V \propto n$
 $P \propto 1/V$
 $V \propto T$


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Ideal Gas Law

Putting it all together:

$$P \propto T$$
$$V \propto n$$
$$P \propto 1/V$$
$$V \propto T$$
$$PV \propto nT$$

$PV = n R T$ where R is the "ideal gas constant"




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$PV = nRT$

UNITS! UNITS! UNITS! (Still Joe's 1st Rule of Chemistry)

What should the units be?

It doesn't really matter – with one exception!



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The Exception

Temperature!

We want the correct limiting behavior.

What happens if the temperature reaches absolute 0?


The molecules stop moving ($KE=0$), the temperature goes to zero and so the pressure should go to 0!



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UNITS! UNITS! UNITS!

T ≡ Kelvin
n ≡ moles
V = ?
P = ?



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UNITS! UNITS! UNITS!


What are the SI units?

Volume

m^3 – volume is cubic distance

Pressure

N/m^2 (Force/area)
 $kg\ s^{-2}\ m^{-1}$ also called a "Pascal"



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UNITS! UNITS! UNITS!


What are the common units?

Volume

Liter

Pressure

atm
mmHg




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UNITS! UNITS! UNITS!

T = Kelvin
N = moles
V = liter
P = atm

Let "R" be your guide




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R has units!

There are a couple different R values that are frequently used.

$R = 0.082058 \frac{\text{L atm}}{\text{mol K}}$ - common for gas dynamics

$R = 8.314 \frac{\text{J}}{\text{mol K}}$ - more common for thermo




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PV=nRT

$PV = nRT$

$R = 0.082058 \frac{\text{L atm}}{\text{mol K}}$

To get everything to cancel:
P = atm n = mol
V = L T = K



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It's the IDEAL gas law – when is a gas IDEAL

What makes an ideal gas, ideal?

1. The volume of the molecules is negligible << the empty space
2. The molecules don't interact with each other – there is no attraction or repulsion between them.

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Sample Problem

A balloon is filled with 1.0 gram of hydrogen at STP, what is its volume?

P = 1 atm, T = 298 K @ thermodynamic STP

P = 1 atm, T = 273 K @ gaseous STP

$$1.0 \text{ g H}_2 * \frac{1 \text{ mol H}_2}{2.016 \text{ g H}_2} = 0.496 \text{ mol}$$

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Sample Problem

A balloon is filled with 1 gram of hydrogen at STP, what is its volume?

P V = nRT


$$1 \text{ atm } V = (0.496 \text{ mol}) * (0.082058 \text{ Latm/mol K}) * 273 \text{ K}$$
$$V = 11.1 \text{ L}$$

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Clicker Question

A 1 L glass flask is filled with He gas at STP. The temperature was increased to 100°C, what is the pressure in the flask?

A. 1 atm
B. 0.366 atm
C. 1.366 atm
D. 100 atm
E. 0.732 atm




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Clicker Question

A 1 L glass flask is filled with He gas at STP. The temperature was increased to 100°C, what is the pressure in the flask?

$P = 1 \text{ atm} \quad T = 273 \text{ K} \quad V = 1 \text{ L} \quad n = ?$
 $P = ? \quad T = 100 \text{ C} = 373 \text{ K} \quad V = 1 \text{ L} \quad n = ?$

Two ways to go!




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Clicker Question

A 1 L glass flask is filled with He gas at STP. The temperature was increased to 100°C, what is the pressure in the flask?

$P = 1 \text{ atm} \quad T = 273 \text{ K} \quad V = 1 \text{ L} \quad n = ?$
 $P = ? \quad T = 100 \text{ C} = 373 \text{ K} \quad V = 1 \text{ L} \quad n = ?$

Find n
 $PV = nRT$
 $1 \text{ atm} * 1 \text{ L} = n (0.082056 \text{ Latm/mol K}) (273 \text{ K})$
 $n = 0.0446 \text{ mol}$



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Clicker Question

A 1 L glass flask is filled with He gas at STP. The temperature was increased to 100°C, what is the pressure in the flask?

$P = 1 \text{ atm}$ $T = 273 \text{ K}$ $V = 1 \text{ L}$ $n = 0.0446 \text{ mol}$
 $P = ?$ $T = 373 \text{ K}$ $V = 1 \text{ L}$ $n = 0.0446 \text{ mol}$

Use the n to find P
 $PV = nRT$
 $P * 1 \text{ L} = (0.0446 \text{ mol}) (0.082056 \text{ Latm/mol K}) (373 \text{ K})$
 $P = 1.366 \text{ atm}$

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Second Way – throw out what’s constant

A 1 L glass flask is filled with He gas at STP. The temperature was increased to 100°C, what is the pressure in the flask?

$P = 1 \text{ atm}$ $T = 273 \text{ K}$ $V = 1 \text{ L}$ $n = ?$
 $P = ?$ $T = 373 \text{ K}$ $V = 1 \text{ L}$ $n = ?$

Collect the variables
 $PV = nRT$
 $P/T = nRV$ (n is constant, V is constant, R is constant)
 $P_1/T_1 = P_2/T_2$
 $1 \text{ atm}/273 \text{ K} = P_2/373 \text{ K}$
 $P_2 = 1.366 \text{ atm}$

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IN the balloon, the Pressure is...

A....constant
B....not constant
C...both constant and not constant
D....neither constant or not constant
E...I don't care, but you're a moron.

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Sample Problem #2

A 1.00 L balloon is filled with helium gas at STP. If the balloon is put into a freezer at 5° C, what is its volume?

PV = nRT

You could just use the Ideal Gas Law to calculate the new volume. (You need to calculate n first, but that's easy enough)

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Sample Problem #2

A 1.00 L balloon is filled with helium gas at STP. If the balloon is put into a freezer at 5° C, what is its volume?

PV = nRT

1 atm * 1 L = n (0.082058 Latm/mol K) * 273 K
n = 0.0446 mol
1 atm * V = (0.0446 mol) (0.082058 Latm/mol K)*278 K
V = 1.02 L

There is, however, an easier way!

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Sample Problem #2

A 1 L balloon is filled with helium gas at STP. If the balloon is put into a freezer at 5° C, what is its volume?

The pressure and the number of moles of gas remain constant throughout the experiment, so...

PV = nRT

$$\frac{V}{T} = \frac{nR}{P}$$

Everything on the right remains constant.

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

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Sample Problem #2

A 1 L balloon is filled with helium gas at STP. If the balloon is put into a freezer at 5° C, what is its volume?

$$\frac{V_f}{T_f} = \frac{V_i}{T_i}$$
$$\frac{V_f}{278 \text{ K}} = \frac{1 \text{ L}}{273 \text{ K}}$$
$$V_f = 1.02 \text{ L}$$

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Clicker Question #2

28.8 g of dry ice (frozen CO₂) is allowed to sublime (go from solid to gas) inside of a large balloon. What will be the volume of the balloon at a temperature of 22°C and 742 mmHg?

A. 1.2 L
B. 714 L
C. 0.021 L
D. 16 L

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Clicker Question #2

28.8 g of dry ice (frozen CO₂) is allowed to sublime (go from solid to gas) inside of a large balloon. What will be the volume of the balloon at a temperature of 22°C and 742 mmHg?

$$PV = nRT \quad 28.8 \text{ g CO}_2 \cdot \frac{1 \text{ mol CO}_2}{44.01 \text{ g CO}_2} = 0.654 \text{ mol CO}_2$$
$$V = \frac{nRT}{P}$$
$$T = 22 \text{ C} + 273.15 = 295 \text{ K}$$
$$P = 742 \text{ mm Hg} \cdot \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 0.976 \text{ atm}$$
$$V = \frac{(0.654 \text{ mol}) \cdot (0.082058 \text{ L atm/mol K}) \cdot (295 \text{ K})}{0.976 \text{ atm}}$$
$$V = 16.2 \text{ L}$$

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Clicker Question

Iron can be reacted with nitrogen to yield iron nitride in the reaction:
 $3 \text{Fe (s)} + \text{N}_2(\text{g}) \rightarrow \text{Fe}_3\text{N}_2(\text{s})$

10.0 g Fe and 2.00 g N_2 are placed in a 2.00 L flask that was initially at STP (before adding the reactants). The reaction was initiated. If the final temperature of the flask is 25°C, what is the final pressure in the flask?

A. 0.14 atm
B. 1.14 atm
C. 1.23 atm
D. 1.8 atm
E. 0.8 atm

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Clicker Question

10.0g Fe (1 mol/55.85 g) = 0.179 mol
2.00 g N_2 (1 mol/28.014 g) = 0.0714 mol

$3 \text{Fe (s)} + \text{N}_2(\text{g}) \rightarrow \text{Fe}_3\text{N}_2(\text{s})$

I	0.179 mol	0.0714 mol	0
C	-3x	-x	+x
E			

$0.179 \text{ mol} - 3x = 0$
 $x = 0.0597$

$0.0714 - x = 0$
 $x = 0.0714$

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Clicker Question

10.0g Fe (1 mol/55.85 g) = 0.179 mol
2.00 g N_2 (1 mol/28.014 g) = 0.0714 mol


$3 \text{Fe (s)} + \text{N}_2(\text{g}) \rightarrow \text{Fe}_3\text{N}_2(\text{s})$

I	0.179 mol	0.0714 mol	0
C	-3x	-0.0597	+0.0597
E	0	0.0117	0.0597

Only the N_2 causes pressure

$P = nRT/V = 0.0117 \text{ mol} \cdot 0.08206 \cdot 298\text{K}/2$
 $P = 0.143 \text{ atm}$

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$P/T = nR/V = \text{constant}$

$1 \text{ atm}/273 \text{ K} = x \text{ atm}/298 \text{ K}$

$x = 1.09 \text{ atm}$

Total pressure = $1.09 \text{ atm} + 0.14 \text{ atm}$
= 1.23 atm
