

Pre-AP Chemistry

September 4, 2011

19. The Mole I



$$N_A = 6.022 \times 10^{23}$$

Outline

- Small Particles, Big Numbers
- Avogadro's Number
- Using Moles

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 - Molar Mass
 - Moles in Chemical Equations

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Small Particles, Big Numbers

- So far, we've talked about really, really, really, really, small things
 - Electrons
 - Protons
 - Neutrons
 - Nuclei
 - Atoms
 - Bonds
 - Molecules



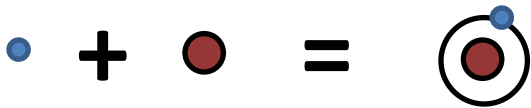
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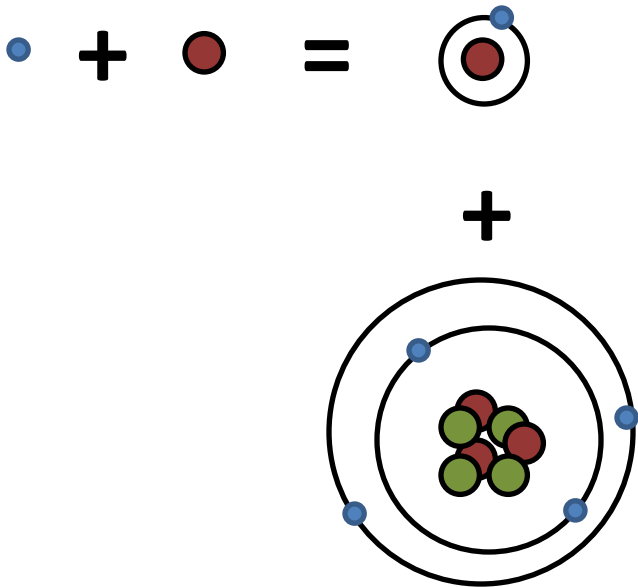
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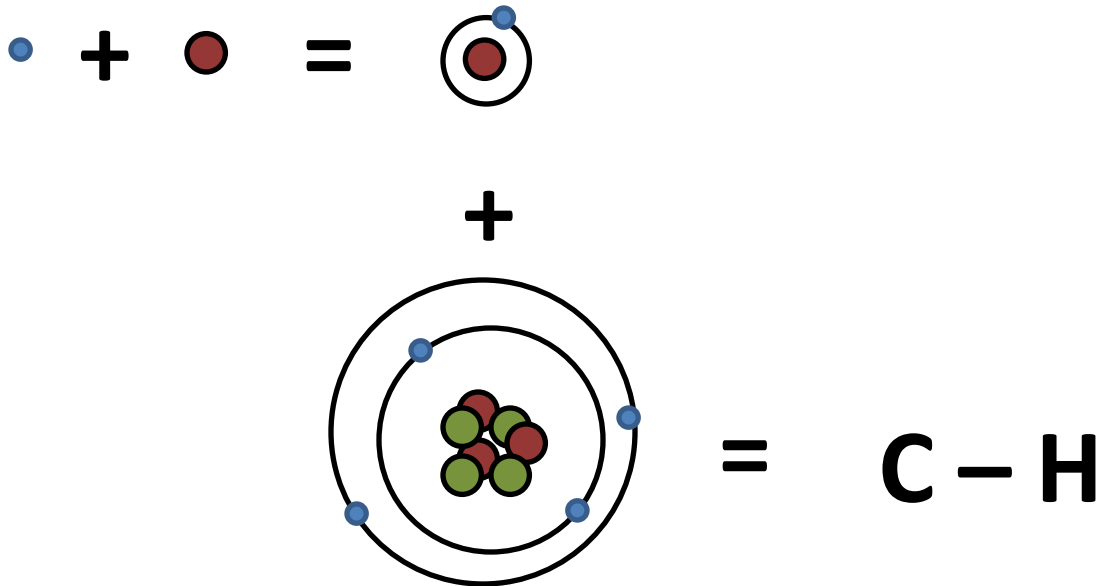
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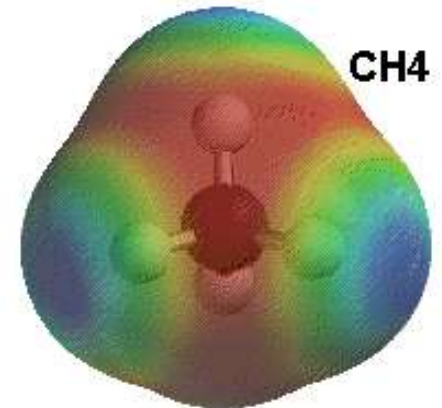
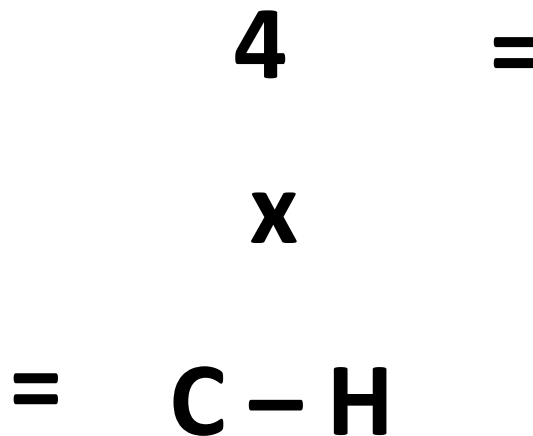
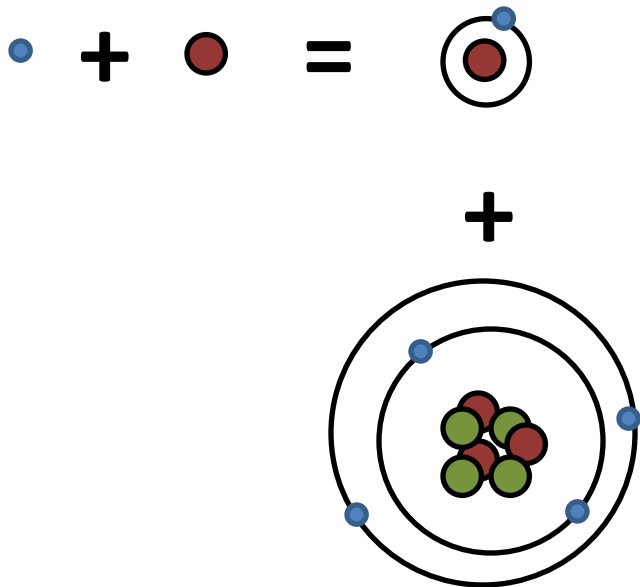
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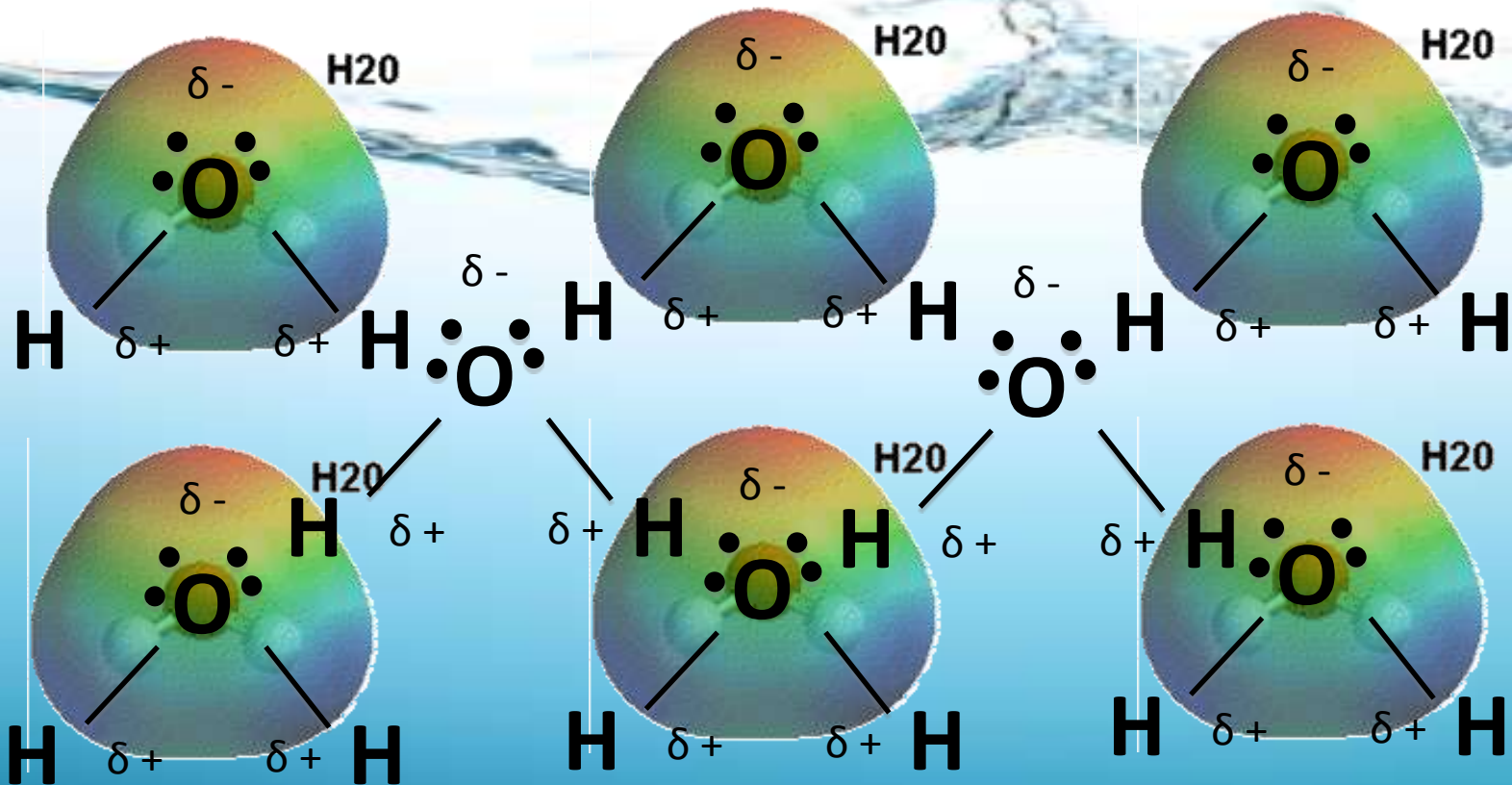
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Small Particles, Big Numbers

- We're getting a little bigger with intermolecular forces ...



Small Particles, Big Numbers

- But there are lots and lots and lots of these small things around us ...

Estimated Number of Chopsticks Produced in China per Year:

Small Particles, Big Numbers

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**Estimated Number of Chopsticks Produced in
China per Year: $4.5 \times 10^{10} = 45 \text{ billion}$**

Small Particles, Big Numbers

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Estimated Number of Chopsticks Produced in China per Year: $4.5 \times 10^{10} = 45 \text{ billion}$

Number of molecules of O_2 we inhale with every breath :

Small Particles, Big Numbers

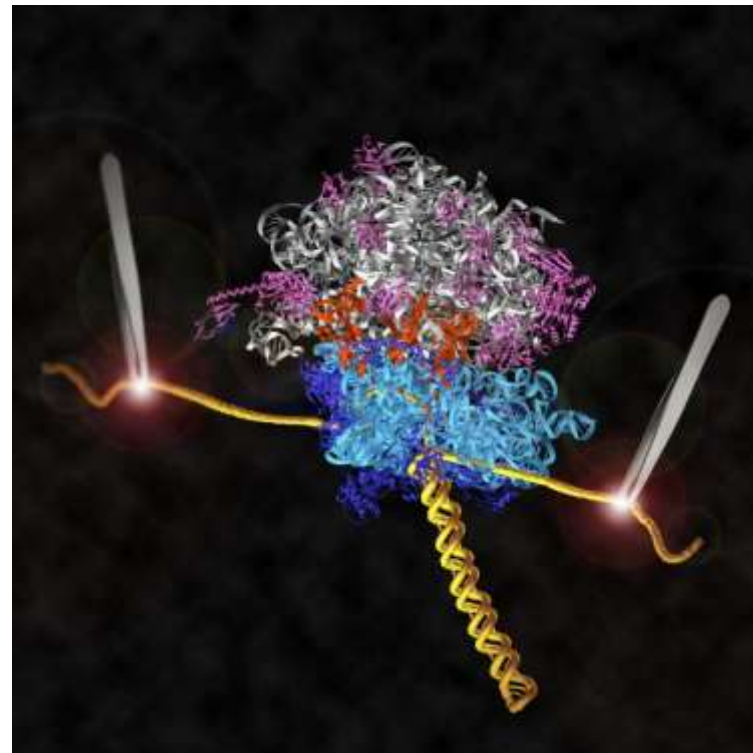
- But there are lots and lots and lots of these small things around us ...

Estimated Number of Chopsticks Produced in China per Year: $4.5 \times 10^{10} = 45 \text{ billion}$

Number of molecules of O_2 we inhale with every breath : $2.6 \times 10^{21} = 2.6 \text{ thousand billion billion}$

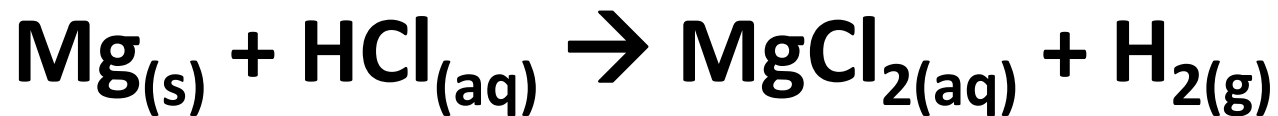
Small Particles, Big Numbers

- But we want to know to know about chemical reactions
- We want to know how what we observe macroscopically is explained by what happens microscopically
- Not many people do experiments with single molecules ...



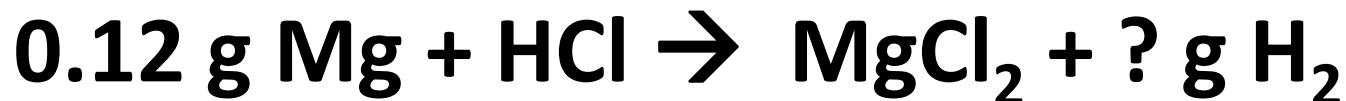
Small Particles, Big Numbers

- Consider the following reaction ...



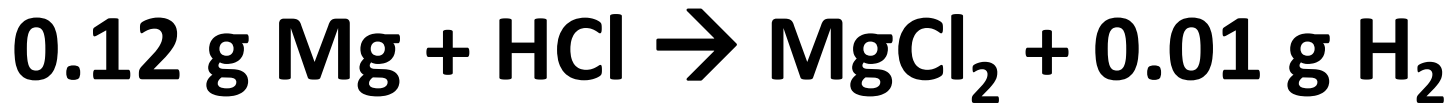
Small Particles, Big Numbers

- How many **grams** of hydrogen gas are released?



Small Particles, Big Numbers

- How many **grams** of hydrogen gas are released?



- How many **atoms** of Mg are needed to make one **molecule** of H₂?



- We need a way to convert **grams** to **atoms / molecules**!

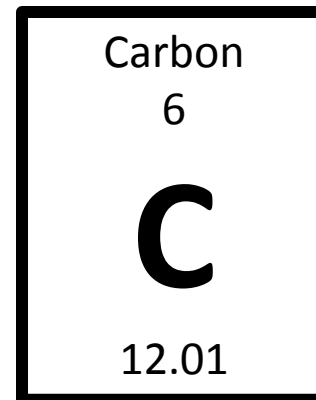
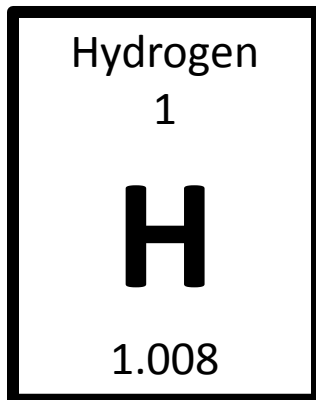
Atomic Mass Units

- Recall atomic mass units:

$$m_{^{12}\text{C}} = 1.993 \times 10^{-26} \text{ kg} = 12 \text{ amu}$$

$$1 \text{ amu} = \frac{1.993 \times 10^{-26}}{12} \text{ kg}$$

$$m_{\text{H}} = 1.673 \times 10^{-27} \text{ kg} \times \frac{12 \text{ amu}}{1.993 \times 10^{-26} \text{ kg}} = 1.0079 \text{ amu}$$



Small Particles, Big Numbers

- In atomic mass units, what mass of Mg was needed to make what mass of H₂ in our experiment?

Small Particles, Big Numbers

- In atomic mass units, what mass of Mg was needed to make what mass of H₂ in our experiment?

7.23×10^{22} amu Mg + HCl

\rightarrow MgCl₂ + 5.99×10^{21} amu H₂

Small Particles, Big Numbers

- In atomic mass units, what mass of Mg was needed to make what mass of H₂ in our experiment?

7.23 x 10²² amu Mg + HCl

→ MgCl₂ + 5.99 x 10²¹ amu H₂

- What are the atomic masses of Mg and H₂ in atomic mass units?
- How many **atoms** of Mg were needed to make one **molecule** of H₂?

Small Particles, Big Numbers

- In atomic mass units, what mass of Mg was needed to make what mass of H₂ in our experiment?

7.23×10^{22} amu Mg + HCl

$\rightarrow \text{MgCl}_2 + 5.99 \times 10^{21}$ amu H₂

- What are the atomic masses of Mg and H₂ in atomic mass units?
- How many **atoms** of Mg were needed to make one **molecule** of H₂?

2.98×10^{21} atoms Mg + HCl

$\rightarrow \text{MgCl}_2 + 2.98 \times 10^{21}$ molecules H₂

Small Particles, Big Numbers

- These numbers still aren't very convenient ...
- Can we reduce them further?

2.98×10^{21} atoms Mg + HCl

$\rightarrow \text{MgCl}_2 + 2.98 \times 10^{21}$ molecules H_2

Small Particles, Big Numbers

- These numbers still aren't very convenient ...
- ... but we have our final answer.



1 atom of Mg was needed to make 1 molecule of H₂

Small Particles, Big Numbers

- There has to be a faster way ...

1. Mass in kg →

2. Mass in amu →

3. Number of atoms / molecules →

4. Ratio of molecules →

5. Simple chemical equation

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Avogadro's Number

- Avogadro invented a convenient way to go from g to molecules
- **Avogadro's Number** = $N_A = 6.022 \times 10^{23}$ particles = 1 mole
- Where did he get this number?



$$m_{12C} = 1.993 \times 10^{-26} \text{ kgC} = 12 \text{ amuC}$$

$$12 \text{ gC} = 0.012 \text{ kgC} \times \frac{1 \text{ atomC}}{1.993 \times 10^{-26} \text{ kgC}}$$

$$12 \text{ gC} = 6.022 \times 10^{23} \text{ atomsC}$$

One carbon atom weighs 12 amu.

One mole of carbon atoms weighs 12 g.

Why is this useful?

Avogadro's Number

- The **mass of one mole** of a substance **in grams** always equals the **mass of one particle** of that substance **in amu!**

	C	H	C ₂ H ₆
Mass of one particle (amu)	12	1	30
Mass of one mole (g)	12	1	30

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Molar Mass

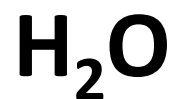
- We call the mass of one mole of a substance its molar mass

$$\text{molar mass of X} = \text{mass of X} / \text{mole of X}$$

- The molar mass of a molecule is the sum of the molar masses of its atoms

Mini Quiz

- What are the molar masses of the following compounds?



- How many moles are in 10 g of the compounds above?

Small Particles, Big Numbers



- How many **moles** of Mg interact with how many **moles** of HCl to make one **mole** of H₂?

Small Particles, Big Numbers



- How many **moles** of Mg interact with how many **moles** of HCl to make one **mole** of H₂?



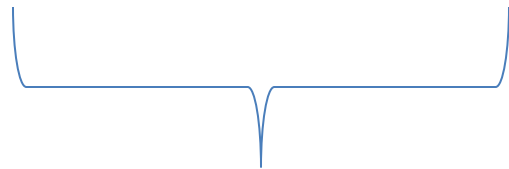
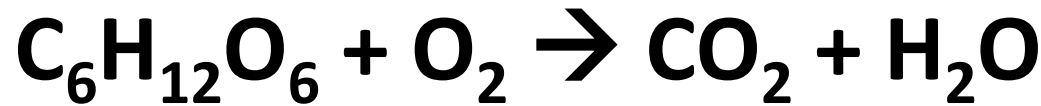
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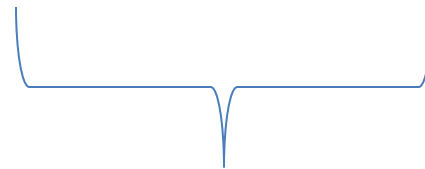
- Small Particles, Big Numbers
 - Atomic Mass Units
 - Chemical Reactions
- Avogadro's Number
- Using Moles
 - Molar Mass
 - Moles in Chemical Equations

Chemical Equations

“Glucose and oxygen yield carbon dioxide and water.”



Reactants



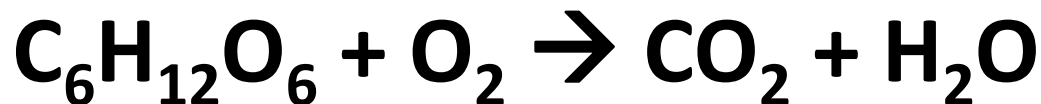
Products

“Glucose is a reactant. Glucose and oxygen are reactants.”

“Water is a product of respiration.”

Chemical Equations

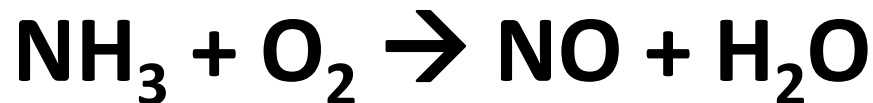
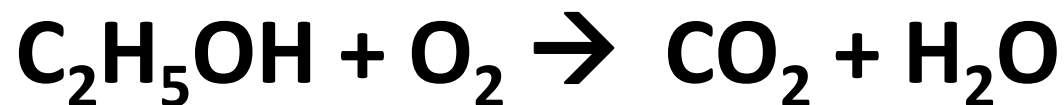
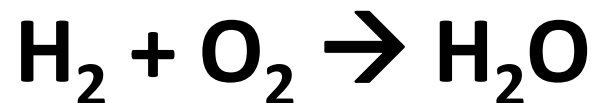
- Lavoisier: mass must be conserved in a chemical reaction
- Elements in chemical reactions do not usually turn into other elements (more on nuclear chemistry next semester)
- To conserve mass, the number of atoms of each element must be equal on both sides of a chemical equation



- We call a chemical equation that conserves mass **balanced**.
- Is the above equation balanced?
- What do we need to do to balance it?

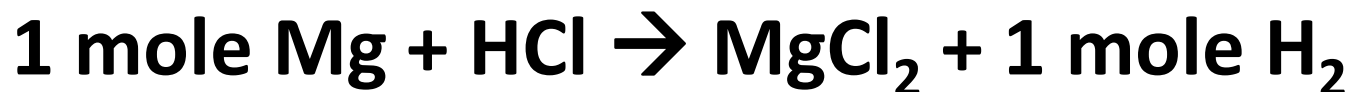
Mini Quiz

- Balance the following chemical equations:



Moles in Chemical Equations

- Let's summarize our results ...

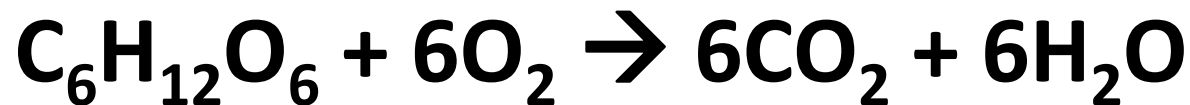


Notice something?

Moles in Chemical Equations

- We can read a chemical equation two ways ...

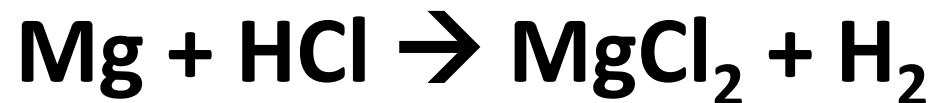
“**One mole** of glucose reacts with **six moles** of oxygen gas to produce **six moles** of carbon dioxide and **six moles** of water.”



“**One molecule** of glucose reacts with **six molecules** of oxygen gas to produce **six molecules** of carbon dioxide and **six molecules** of water.”

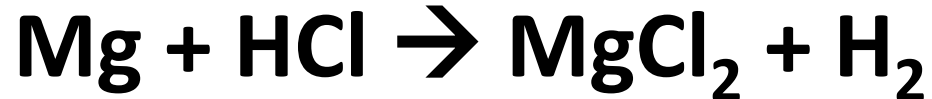
Small Particles, Big Numbers

Are we done?



Small Particles, Big Numbers

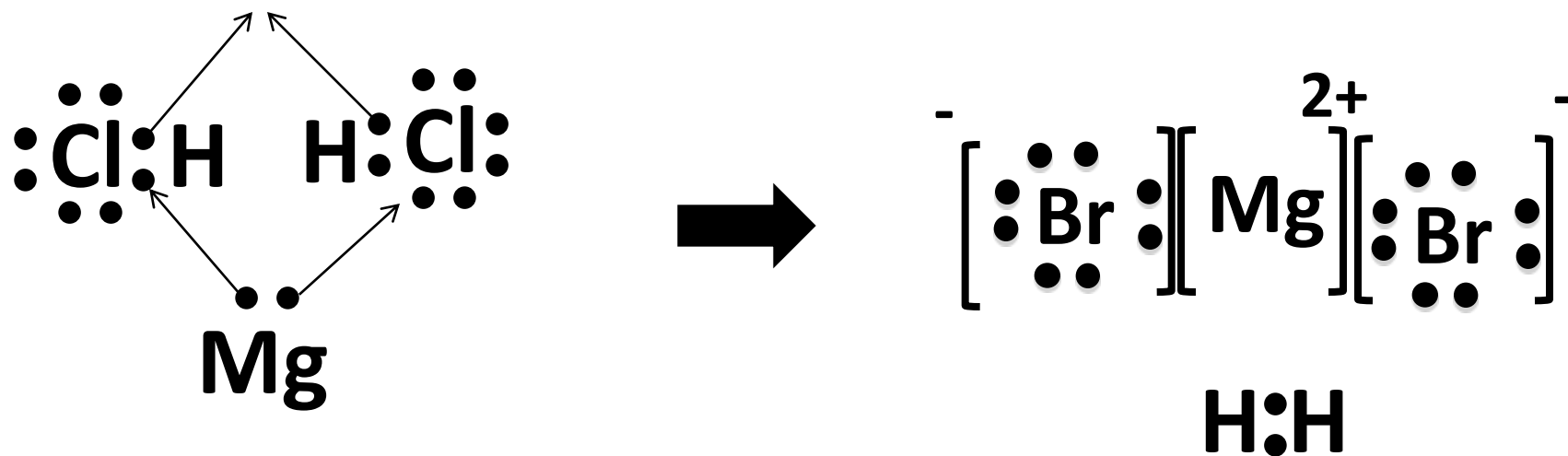
Are we done?



Done!

Small Particles, Big Numbers

Are we done?



Done!

Summary

- Avogadro's number gives a useful unit for counting large numbers of particles
- The mole is a useful unit for connecting macroscopic and microscopic quantities
- Balanced chemical equations show the products and reactants of a chemical reaction

Homework

- Introduction to the Mole Handout