Stoichiometry
Limiting Reactants

DR. MIOY T. HUYNH
YALE UNIVERSITY
CHEMISTRY 161
FALL 2018

www.mioy.org/chem161

REMEMBER THIS?

THE MOLE IS CENTRAL

use: $\dfrac{6.022\times10^{23}\text{ “thing”}}{1\text{ mol}}$ or $\dfrac{1\text{ mol}}{6.022\times10^{23}\text{ “things”}}$

 # ATOMS
– or –
 # MOLECULES ⟷ **# MOLES** ⟷ **MASS (in grams)**

use molar masses from periodic table: $\dfrac{12.01\text{ g C}}{1\text{ mol C}}$ or $\dfrac{1\text{ mol C}}{12.01\text{ g C}}$

SUMMARIZING STOICHIOMETRY RELATIONSHIPS

THE MOLE IS ***STILL*** CENTRAL

MASS
VOLUME
MOLES

BALANCED CHEMICAL EQUATION

$\text{mole}_1 \longrightarrow \text{mole}_2$

MASS
VOLUME
MOLES

GIVEN
reactant or product

LOOKING FOR
reactant or product

*I hope now you understand why I say to convert to moles before you do anything else. It's because a balanced chemical equation gives us **mole-to-mole ratios** that we can use to convert between one reactant/product to another reactant/product.*

How do I read a chemical equation?

COEFFICIENTS
Tell us the *relative* amounts of reactants/products

SUBSCRIPTS
Tell us the # of atoms in a molecule

PHASES
Tell us the nature of reactants/products

$$2H_2\,(g) \quad + \quad O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

- Subscripts are not conserved!
- Coefficients have no real meaning by themselves…
- RATIO of coefficient is what's important.
- Read it like a recipe:

"For every 2 H_2 molecules, we need 1 O_2 molecule to produce 2 H_2O molecules."

WE HAVE NOT CONSIDERED CASES WHERE WE HAVE LIMITED AMOUNTS OF BOTH REACTANTS!

$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

C) If you have 8 moles of hydrogen and 6 moles of oxygen, how many moles of water can you make?

$$2H_2\ (g) \quad + \quad 1O_2\ (g) \quad \rightarrow \quad 2H_2O\ (g)$$

A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\ \text{mol H}_2 \times \frac{2\ \text{mol H}_2\text{O}}{2\ \text{mol H}_2} = 8\ \text{mol H}_2\text{O}$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

C) If you have 8 moles of hydrogen and 6 moles of oxygen, how many moles of water can you make?

$$2H_2\ (g) \quad + \quad 1O_2\ (g) \quad \rightarrow \quad 2H_2O\ (g)$$

A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8 \text{ mol } H_2 \times \frac{2 \text{ mol } H_2O}{2 \text{ mol } H_2} = 8 \text{ mol } H_2O$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} = 12 \text{ mol } H_2O$$

C) If you have 8 moles of hydrogen and 6 moles of oxygen, how many moles of water can you make?

$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

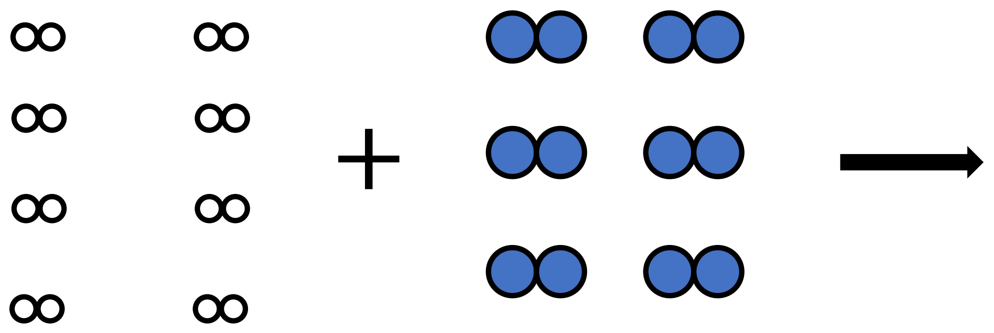
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\text{ mol }H_2 \times \frac{2\text{ mol }H_2O}{2\text{ mol }H_2} = 8\text{ mol }H_2O$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6\text{ mol }O_2 \times \frac{2\text{ mol }H_2O}{1\text{ mol }O_2} = 12\text{ mol }H_2O$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

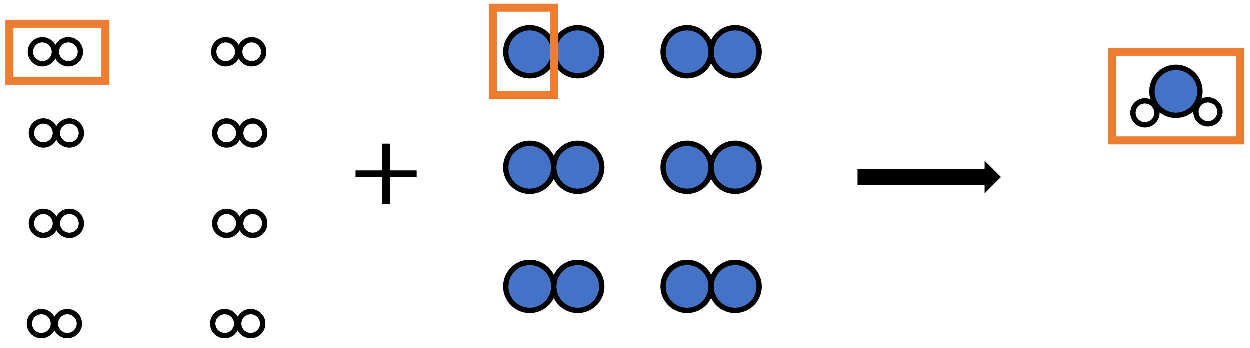
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8 \text{ mol } H_2 \times \frac{2 \text{ mol } H_2O}{2 \text{ mol } H_2} = 8 \text{ mol } H_2O$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6 \text{ mol } O_2 \times \frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2} = 12 \text{ mol } H_2O$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

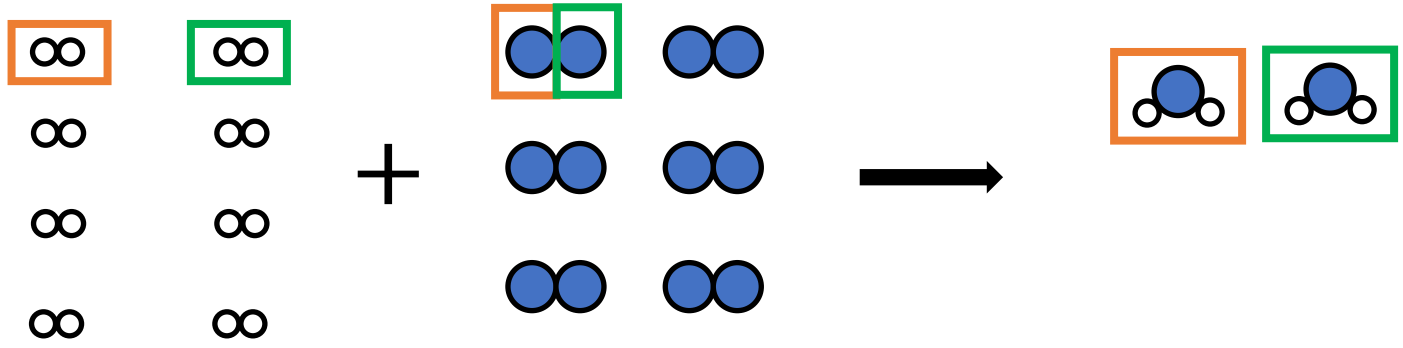
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\text{ mol }H_2 \times \frac{2\text{ mol }H_2O}{2\text{ mol }H_2} = 8\text{ mol }H_2O$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6\text{ mol }O_2 \times \frac{2\text{ mol }H_2O}{1\text{ mol }O_2} = 12\text{ mol }H_2O$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

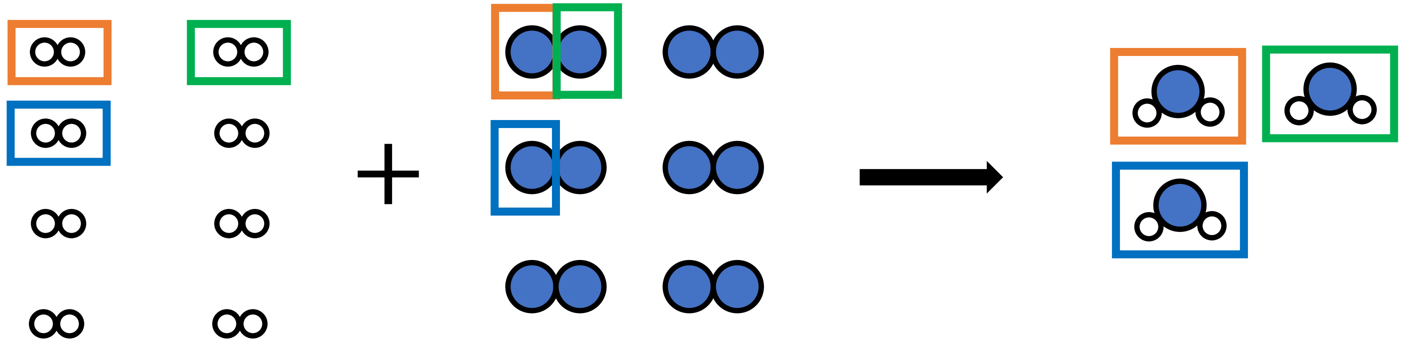
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\text{ mol H}_2 \times \frac{2\text{ mol H}_2\text{O}}{2\text{ mol H}_2} = 8\text{ mol H}_2\text{O}$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6\text{ mol O}_2 \times \frac{2\text{ mol H}_2\text{O}}{1\text{ mol O}_2} = 12\text{ mol H}_2\text{O}$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

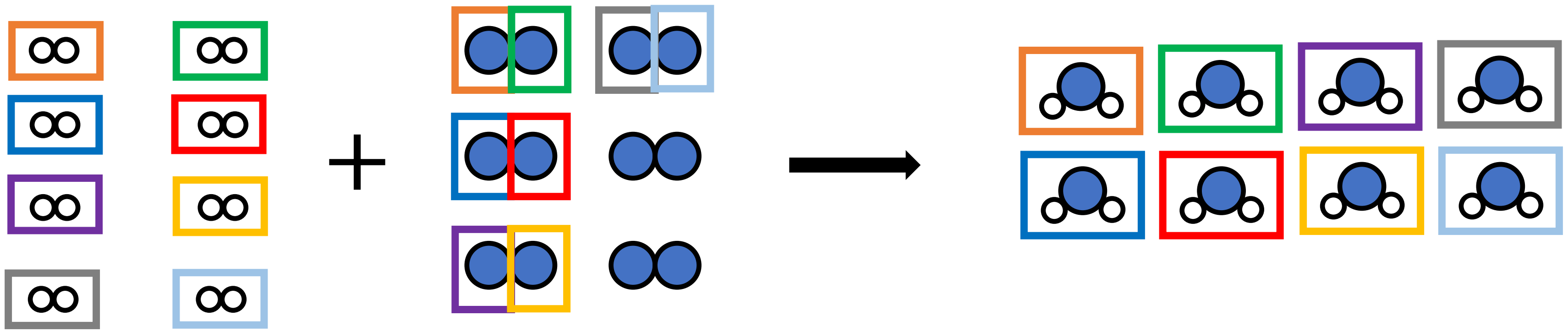
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\ \text{mol H}_2 \times \frac{2\ \text{mol H}_2\text{O}}{2\ \text{mol H}_2} = 8\ \text{mol H}_2\text{O}$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6\ \text{mol O}_2 \times \frac{2\ \text{mol H}_2\text{O}}{1\ \text{mol O}_2} = 12\ \text{mol H}_2\text{O}$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

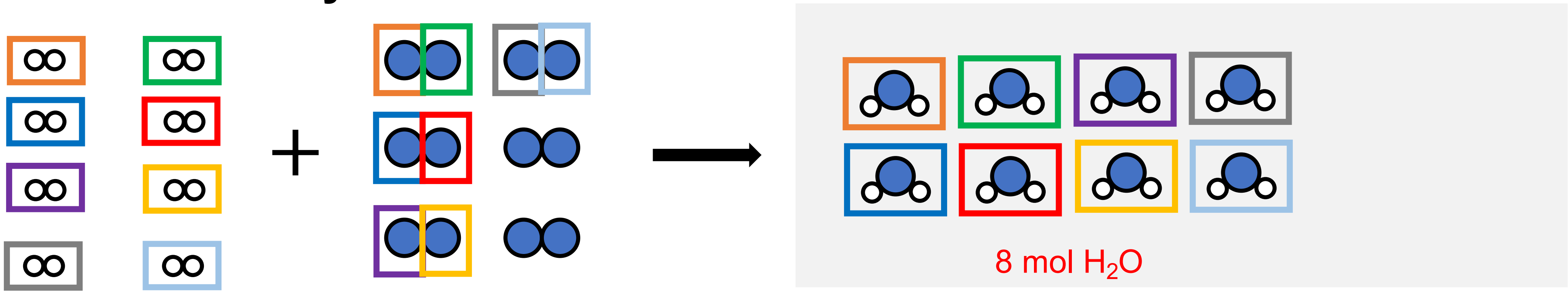
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\text{ mol }H_2 \times \frac{2\text{ mol }H_2O}{2\text{ mol }H_2} = 8\text{ mol }H_2O$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6\text{ mol }O_2 \times \frac{2\text{ mol }H_2O}{1\text{ mol }O_2} = 12\text{ mol }H_2O$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



$$2H_2\,(g) \quad + \quad 1O_2\,(g) \quad \rightarrow \quad 2H_2O\,(g)$$

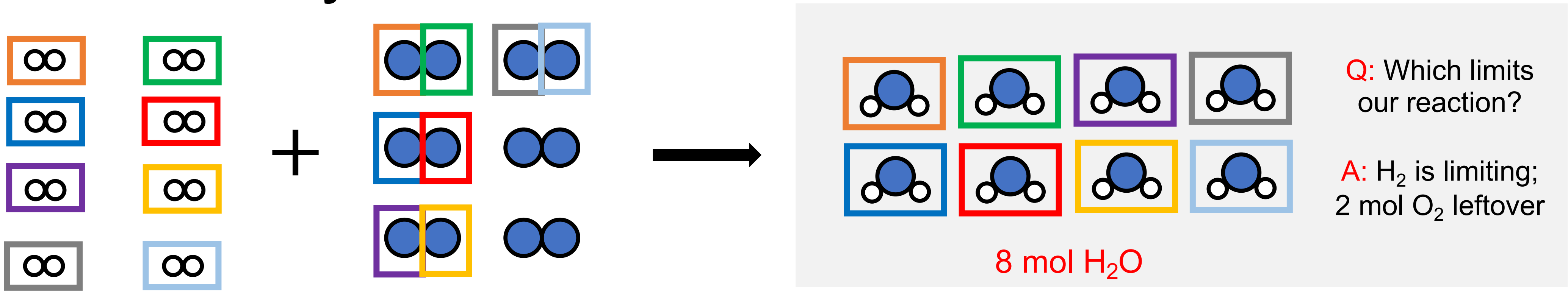
A) If you have 8 moles of hydrogen and all the oxygen you need, how many moles of water can you make?

$$8\text{ mol }H_2 \times \frac{2\text{ mol }H_2O}{2\text{ mol }H_2} = 8\text{ mol }H_2O$$

B) If you have 6 moles of oxygen and all the hydrogen you need, how many moles of water can you make?

$$6\text{ mol }O_2 \times \frac{2\text{ mol }H_2O}{1\text{ mol }O_2} = 12\text{ mol }H_2O$$

C) If you have 8 moles of hydrogen <u>and</u> 6 moles of oxygen, how many moles of water can you make?



Okay, but I don't want to draw pictures every time… Can you explain differently?

$$\underline{\ 2\ }\ H_2\ (g)\ +\ \underline{\ 1\ }\ O_2\ (g)\ \rightarrow\ \underline{\ 2\ }\ H_2O\ (g)$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$8\ \text{mol}\ H_2 \times \frac{2\ \text{mol}\ H_2O}{2\ \text{mol}\ H_2} = 8\ \text{mol}\ H_2O$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$6\ \text{mol}\ O_2 \times \frac{2\ \text{mol}\ H_2O}{1\ \text{mol}\ O_2} = 12\ \text{mol}\ H_2O$$
3. Reactant that *limits* amount of products formed is **limiting reactant**.

H_2 produces less H_2O so it is limiting.

Okay, but I don't want to draw pictures every time… Can you explain differently?

$\underline{\ 2\ }\ H_2\ (g)\ +\ \underline{\ 1\ }\ O_2\ (g)\ \rightarrow\ \underline{\ 2\ }\ H_2O\ (g)$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$8\ \text{mol}\ H_2 \times \frac{2\ \text{mol}\ H_2O}{2\ \text{mol}\ H_2} = 8\ \text{mol}\ H_2O$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$6\ \text{mol}\ O_2 \times \frac{2\ \text{mol}\ H_2O}{1\ \text{mol}\ O_2} = 12\ \text{mol}\ H_2O$$
3. Reactant that *limits* amount of products formed is **limiting reactant**.

H_2 produces less H_2O so it is limiting.

METHOD 2

1. Start with one reactant and determine how much of the other reactant you *need*.
$$8\ \text{mol}\ H_2 \times \frac{1\ \text{mol}\ O_2}{2\ \text{mol}\ H_2} = 4\ \text{mol}\ O_2$$
2. Compare what you *have* vs. what you *need*:
   Have: 6 mol O_2
   Need: 4 mol O_2
3. We *have* more O_2 than we *need*
   → O_2 excess
   → **H_2 is limiting.**

CHOOSE THE METHOD THAT WORKS BEST FOR YOU!

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\_\_\_\ N_2\ (g) + \_\_\_\ H_2\ (g) \rightarrow \_\_\_\ NH_3\ (g)$$

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\ (g) + \underline{\ 3\ }\ H_2\ (g) \rightarrow \underline{\ 2\ }\ NH_3\ (g)$$

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\,(g) + \underline{\ 3\ }\ H_2\,(g) \rightarrow \underline{\ 2\ }\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\text{ g N}_2 \times \frac{1\text{ mol N}_2}{28.02\text{ g N}_2} = 6.00\text{ mol N}_2$$

$$12.096\text{ g H}_2 \times \frac{1\text{ mol H}_2}{2.016\text{ g H}_2} = 6.00\text{ mol H}_2$$

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$\underline{\ 1\ }\ N_2\,(g) + \underline{\ 3\ }\ H_2\,(g) \rightarrow \underline{\ 2\ }\ NH_3\,(g)$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\text{ g N}_2 \times \frac{1\text{ mol N}_2}{28.02\text{ g N}_2} = 6.00\text{ mol N}_2$$

$$12.096\text{ g H}_2 \times \frac{1\text{ mol H}_2}{2.016\text{ g H}_2} = 6.00\text{ mol H}_2$$

METHOD 1

METHOD 2

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{1}\ N_2\,(g) + \underline{3}\ H_2\,(g) \rightarrow \underline{2}\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \mathrm{g\ N_2} \times \frac{1\ \mathrm{mol\ N_2}}{28.02\ \mathrm{g\ N_2}} = 6.00\ \mathrm{mol\ N_2}$$

$$12.096\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g\ H_2}} = 6.00\ \mathrm{mol\ H_2}$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.

$$6.00\ \mathrm{mol\ N_2} \times \frac{2\ \mathrm{mol\ NH_3}}{1\ \mathrm{mol\ N_2}} = 12.0\ \mathrm{mol\ NH_3}$$

METHOD 2

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\,(g) + \underline{\ 3\ }\ H_2\,(g) \rightarrow \underline{\ 2\ }\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \text{g N}_2 \times \frac{1\ \text{mol N}_2}{28.02\ \text{g N}_2} = 6.00\ \text{mol N}_2$$

$$12.096\ \text{g H}_2 \times \frac{1\ \text{mol H}_2}{2.016\ \text{g H}_2} = 6.00\ \text{mol H}_2$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.

$$6.00\ \text{mol N}_2 \times \frac{2\ \text{mol NH}_3}{1\ \text{mol N}_2} = 12.0\ \text{mol NH}_3$$

2. Assume *other* reactant is limiting and then determine amount of product you can form.

$$6.00\ \text{mol H}_2 \times \frac{2\ \text{mol NH}_3}{3\ \text{mol H}_2} = 4.00\ \text{mol NH}_3$$

METHOD 2

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{1}\ N_2\,(g) + \underline{3}\ H_2\,(g) \rightarrow \underline{2}\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\text{ g N}_2 \times \frac{1\text{ mol N}_2}{28.02\text{ g N}_2} = 6.00\text{ mol N}_2$$

$$12.096\text{ g H}_2 \times \frac{1\text{ mol H}_2}{2.016\text{ g H}_2} = 6.00\text{ mol H}_2$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.

$$6.00\text{ mol N}_2 \times \frac{2\text{ mol NH}_3}{1\text{ mol N}_2} = 12.0\text{ mol NH}_3$$

2. Assume *other* reactant is limiting and then determine amount of product you can form.

$$6.00\text{ mol H}_2 \times \frac{2\text{ mol NH}_3}{3\text{ mol H}_2} = 4.00\text{ mol NH}_3$$

3. Reactant that *limits* amount of products formed is **limiting reactant**.

H_2 produces less NH_3 so it is limiting.

METHOD 2

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\,(g) + \underline{\ 3\ }\ H_2\,(g) \rightarrow \underline{\ 2\ }\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \mathrm{g\ N_2} \times \frac{1\ \mathrm{mol\ N_2}}{28.02\ \mathrm{g\ N_2}} = 6.00\ \mathrm{mol\ N_2}$$

$$12.096\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g\ H_2}} = 6.00\ \mathrm{mol\ H_2}$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$6.00\ \mathrm{mol\ N_2} \times \frac{2\ \mathrm{mol\ NH_3}}{1\ \mathrm{mol\ N_2}} = 12.0\ \mathrm{mol\ NH_3}$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$6.00\ \mathrm{mol\ H_2} \times \frac{2\ \mathrm{mol\ NH_3}}{3\ \mathrm{mol\ H_2}} = 4.00\ \mathrm{mol\ NH_3}$$
3. Reactant that *limits* amount of products formed is **limiting reactant.**

H_2 produces less NH_3 so it is limiting.

METHOD 2

1. Start with one reactant and determine how much of the other reactant you *need*.
$$6.00\ \mathrm{mol\ N_2} \times \frac{3\ \mathrm{mol\ H_2}}{1\ \mathrm{mol\ N_2}} = 18.0\ \mathrm{mol\ H_2}$$

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\ (g)\ +\ \underline{\ 3\ }\ H_2\ (g)\ \rightarrow\ \underline{\ 2\ }\ NH_3\ (g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \mathrm{g\ N_2} \times \frac{1\ \mathrm{mol\ N_2}}{28.02\ \mathrm{g\ N_2}} = 6.00\ \mathrm{mol\ N_2}$$

$$12.096\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g\ H_2}} = 6.00\ \mathrm{mol\ H_2}$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$6.00\ \mathrm{mol\ N_2} \times \frac{2\ \mathrm{mol\ NH_3}}{1\ \mathrm{mol\ N_2}} = 12.0\ \mathrm{mol\ NH_3}$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$6.00\ \mathrm{mol\ H_2} \times \frac{2\ \mathrm{mol\ NH_3}}{3\ \mathrm{mol\ H_2}} = 4.00\ \mathrm{mol\ NH_3}$$
3. Reactant that *limits* amount of products formed is **limiting reactant.**

H_2 produces less NH_3 so it is limiting.

METHOD 2

1. Start with one reactant and determine how much of the other reactant you *need*.
$$6.00\ \mathrm{mol\ N_2} \times \frac{3\ \mathrm{mol\ H_2}}{1\ \mathrm{mol\ N_2}} = 18.0\ \mathrm{mol\ H_2}$$
2. Compare what you *have* vs. what you *need*:
   Have: 6.00 mol H_2
   Need: 18.0 mol H_2

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\ (g) + \underline{\ 3\ }\ H_2\ (g) \rightarrow \underline{\ 2\ }\ NH_3\ (g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \mathrm{g\ N_2} \times \frac{1\ \mathrm{mol\ N_2}}{28.02\ \mathrm{g\ N_2}} = 6.00\ \mathrm{mol\ N_2}$$

$$12.096\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g\ H_2}} = 6.00\ \mathrm{mol\ H_2}$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$6.00\ \mathrm{mol\ N_2} \times \frac{2\ \mathrm{mol\ NH_3}}{1\ \mathrm{mol\ N_2}} = 12.0\ \mathrm{mol\ NH_3}$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$6.00\ \mathrm{mol\ H_2} \times \frac{2\ \mathrm{mol\ NH_3}}{3\ \mathrm{mol\ H_2}} = 4.00\ \mathrm{mol\ NH_3}$$
3. Reactant that *limits* amount of products formed is **limiting reactant.**

H_2 produces less NH_3 so it is limiting.

METHOD 2

1. Start with one reactant and determine how much of the other reactant you *need*.
$$6.00\ \mathrm{mol\ N_2} \times \frac{3\ \mathrm{mol\ H_2}}{1\ \mathrm{mol\ N_2}} = 18.0\ \mathrm{mol\ H_2}$$
2. Compare what you *have* vs. what you *need*:
   Have: 6.00 mol H_2
   Need: 18.0 mol H_2
3. We *have* less H_2 than we *need*

→ **H_2 is limiting.**

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{1}\ N_2\ (g) + \underline{3}\ H_2\ (g) \rightarrow \underline{2}\ NH_3\ (g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \mathrm{g\ N_2} \times \frac{1\ \mathrm{mol\ N_2}}{28.02\ \mathrm{g\ N_2}} = 6.00\ \mathrm{mol\ N_2}$$

$$12.096\ \mathrm{g\ H_2} \times \frac{1\ \mathrm{mol\ H_2}}{2.016\ \mathrm{g\ H_2}} = 6.00\ \mathrm{mol\ H_2}$$

After determining that H_2 is the limiting reactant, then we can continue with the problem.

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\,(g) + \underline{\ 3\ }\ H_2\,(g) \rightarrow \underline{\ 2\ }\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\ \text{g N}_2 \times \frac{1\ \text{mol N}_2}{28.02\ \text{g N}_2} = 6.00\ \text{mol N}_2 \qquad 12.096\ \text{g H}_2 \times \frac{1\ \text{mol H}_2}{2.016\ \text{g H}_2} = 6.00\ \text{mol H}_2$$

After determining that H_2 is the limiting reactant, then we can continue with the problem.

Start with the limiting reactant and use mole-mole ratio to find mole of products:

$$12.096\ \text{g H}_2 \times \frac{1\ \text{mol H}_2}{2.016\ \text{g H}_2} \times \frac{2\ \text{mol NH}_3}{3\ \text{mol H}_2} = 4.000\ \text{mol NH}_3$$

If we have 168.12 g N_2 and 12.096 g H_2, how much NH_3 can we make?

$$\underline{\ 1\ }\ N_2\,(g) + \underline{\ 3\ }\ H_2\,(g) \rightarrow \underline{\ 2\ }\ NH_3\,(g)$$

REMEMBER: If you don't know where to start, convert to moles first!

$$168.12\text{ g N}_2 \times \frac{1\text{ mol N}_2}{28.02\text{ g N}_2} = 6.00\text{ mol N}_2$$

$$12.096\text{ g H}_2 \times \frac{1\text{ mol H}_2}{2.016\text{ g H}_2} = 6.00\text{ mol H}_2$$

After determining that H_2 is the limiting reactant, then we can continue with the problem.

Start with the limiting reactant and use mole-mole ratio to find mole of products:

$$12.096\text{ g H}_2 \times \frac{1\text{ mol H}_2}{2.016\text{ g H}_2} \times \frac{2\text{ mol NH}_3}{3\text{ mol H}_2} = 4.000\text{ mol NH}_3$$

Now use molar mass of NH_3 to convert from moles to mass of NH_3 made:

$$4.000\text{ mol NH}_3 \times \frac{17.034\text{ g NH}_3}{1\text{ mol NH}_3} = 68.14\text{ g NH}_3$$

How do I know when I have a limiting reactant problem?

Only when you are given the amounts (mass, moles, volume) of BOTH reactants.

Pouring an aqueous solution of HCl onto a solid block of Mg metal produces an aqueous solution of $MgCl_2$ and H_2 gas.

$$\underline{\ 1\ }\ Mg\ (s)\ +\ \underline{\ 2\ }\ HCl\ (aq)\ \rightarrow\ \underline{\ 1\ }\ MgCl_2\ (aq)\ +\ \underline{\ 1\ }\ H_2\ (g)$$

How much H_2 gas can be made if we start with 10.0 g Mg and 1.76 mol HCl?

Pouring an aqueous solution of HCl onto a solid block of Mg metal produces an aqueous solution of $MgCl_2$ and H_2 gas.

$\underline{\ 1\ }$ Mg (s) + $\underline{\ 2\ }$ HCl (*aq*) → $\underline{\ 1\ }$ $MgCl_2$ (*aq*) + $\underline{\ 1\ }$ H_2 (*g*)

How much H_2 gas can be made if we start with 10.0 g Mg and 1.76 mol HCl?

$$10.0\text{ g Mg} \times \frac{1\text{ mol Mg}}{24.31\text{ g Mg}} = 0.411\text{ mol Mg}$$

$$1.76\text{ mol HCl}$$

Pouring an aqueous solution of HCl onto a solid block of Mg metal produces an aqueous solution of $MgCl_2$ and H_2 gas.

$$\underline{\ 1\ }\ \mathrm{Mg}\ (s)\ +\ \underline{\ 2\ }\ \mathrm{HCl}\ (aq)\ \rightarrow\ \underline{\ 1\ }\ \mathrm{MgCl_2}\ (aq)\ +\ \underline{\ 1\ }\ \mathrm{H_2}\ (g)$$

How much H_2 gas can be made if we start with 10.0 g Mg and 1.76 mol HCl?

$$10.0\ \mathrm{g\ Mg} \times \frac{1\ \mathrm{mol\ Mg}}{24.31\ \mathrm{g\ Mg}} = 0.411\ \mathrm{mol\ Mg} \qquad 1.76\ \mathrm{mol\ HCl}$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$0.411\ \mathrm{mol\ Mg} \times \frac{1\ \mathrm{mol\ H_2}}{1\ \mathrm{mol\ Mg}} = 0.411\ \mathrm{mol\ H_2}$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$1.76\ \mathrm{mol\ HCl} \times \frac{1\ \mathrm{mol\ H_2}}{2\ \mathrm{mol\ HCl}} = 0.880\ \mathrm{mol\ NH_3}$$
3. Reactant that *limits* amount of products formed is **limiting reactant**.

Mg produces less H_2 so it is limiting.

Pouring an aqueous solution of HCl onto a solid block of Mg metal produces an aqueous solution of $MgCl_2$ and H_2 gas.

$$\underline{\ 1\ }\ \mathrm{Mg}\ (s)\ +\ \underline{\ 2\ }\ \mathrm{HCl}\ (aq)\ \rightarrow\ \underline{\ 1\ }\ \mathrm{MgCl_2}\ (aq)\ +\ \underline{\ 1\ }\ \mathrm{H_2}\ (g)$$

How much H_2 gas can be made if we start with 10.0 g Mg and 1.76 mol HCl?

$$10.0\ \text{g Mg} \times \frac{1\ \text{mol Mg}}{24.31\ \text{g Mg}} = 0.411\ \text{mol Mg}$$

$$1.76\ \text{mol HCl}$$

METHOD 1

1. Assume one reactant is limiting and then determine amount of product you can form.
$$0.411\ \text{mol Mg} \times \frac{1\ \text{mol H}_2}{1\ \text{mol Mg}} = 0.411\ \text{mol H}_2$$
2. Assume *other* reactant is limiting and then determine amount of product you can form.
$$1.76\ \text{mol HCl} \times \frac{1\ \text{mol H}_2}{2\ \text{mol HCl}} = 0.880\ \text{mol NH}_3$$
3. Reactant that *limits* amount of products formed is **limiting reactant.**

Mg produces less H_2 so it is limiting.

METHOD 2

1. Start with one reactant and determine how much of the other reactant you *need*.
$$0.411\ \text{mol Mg} \times \frac{2\ \text{mol HCl}}{1\ \text{mol Mg}} = 0.822\ \text{mol HCl}$$
2. Compare what you *have* vs. what you *need*:
   Have: 1.76 mol HCl
   Need: 0.822 mol HCl
3. We *have* more HCl than we *need*

   → **Mg is limiting.**

Pouring an aqueous solution of HCl onto a solid block of Mg metal produces an aqueous solution of $MgCl_2$ and H_2 gas.

$$\underline{\ 1\ }\ \mathrm{Mg}\ (s)\ +\ \underline{\ 2\ }\ \mathrm{HCl}\ (aq)\ \rightarrow\ \underline{\ 1\ }\ \mathrm{MgCl_2}\ (aq)\ +\ \underline{\ 1\ }\ \mathrm{H_2}\ (g)$$

How much H_2 gas can be made if we start with 10.0 g Mg and 1.76 mol HCl?

$$10.0\ \mathrm{g\ Mg} \times \frac{1\ \mathrm{mol\ Mg}}{24.31\ \mathrm{g\ Mg}} = 0.411\ \mathrm{mol\ Mg} \qquad 1.76\ \mathrm{mol\ HCl}$$

After determining that Mg is the limiting reactant, then we can continue with the problem.

Start with the limiting reactant and use mole-mole ratio to find mole of products:

$$10.0\ \mathrm{g\ Mg} \times \frac{1\ \mathrm{mol\ Mg}}{24.31\ \mathrm{g\ Mg}} \times \frac{1\ \mathrm{mol\ H_2}}{1\ \mathrm{mol\ Mg}} = 0.411\ \mathrm{mol\ H_2}$$

Or use molar mass of H_2 to convert from moles to mass of H_2 made:

$$0.411\ \mathrm{mol\ H_2} \times \frac{2.016\ \mathrm{g\ H_2}}{1\ \mathrm{mol\ H_2}} = 0.829\ \mathrm{g\ H_2}$$