3.3.3: Everyday Life- Grilled Cheese Sandwiches and Omelets

Which video is more exciting?!?

Make sure your volume is turned up!

If you liked the one on the bottom, you have just experienced the excitement of how different amounts of chemicals can affect things. We often use the concept of limiting reagents in everyday life without even realizing it, especially while cooking or preparing a grocery list!

What do  and  have to do with chemistry?

When you cook, often times you can encounter a limiting reagent calculation that you have been doing in your head before you can remember. This page will use the familiarity of an everyday example to teach the steps of a limiting reagent problem.

Here are two things to look for when trying to identify a limiting reagent problem: 1) it should be a task that you start with at least two starting materials and 2) it should form at least one new product. Another main concept found in **all** limiting reagent questions is there will be starting material that *remains* when the task you are doing is complete. There are three methods (A, B, and C) that can be used to **identify the limiting reagent**. This is the most important step of this type of question. As you progress through this page, choose the method that is most intuitive to you.

Jump to Example 2
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Jump to Limiting Reagent Practice

An Example with Two Starting Materials

EXAMPLE 1 I want to have friends over for lunch on Saturday and make grilled cheese sandwiches that require two slices of bread and one slice of cheese. I open the refrigerator to find that I have 40 slices of cheese. I look in the bread box to find that I have 16 slices of bread.

Question 1: Which of my ingredients is the limiting the number of sandwiches I can make?

Question 2: How many sandwiches can I make?

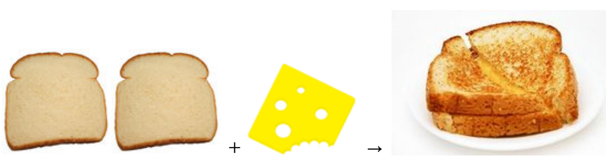
Question 3: How much of my starting material is left over once I am done making sandwiches?

Jump to Step 3 - Identify a Limiting Reagent

Answers

These three steps are the first steps to solving this type of question and will be used in conjunction with ALL three methods A, B, and C.

Step 1) Write out the recipe, also known as an **equation**



2 slices of bread + 1 slice of cheese → 1 grilled cheese sandwich

Step 2) Find Quantity (moles) and Identify useful unit conversions and/or **molar ratios**

What we know:
1) We know we have 40 slices of cheese
2) We know we have 16 slices of bread.

According to the equation written in step 1, these ratios can be written by using the number in front of the ingredient, also known as a **co-efficient**.

2 slices of bread is required for one slice of cheese.

Remember, the powerful thing about ratios is that we can also write them "upside-down".

The following ratios or unit conversions that can be written from this equation are:

$$\frac{\text{1 slice of cheese}}{\text{2 slices of bread}} = \frac{\text{2 slices of bread}}{\text{1 slice of cheese}} \tag{3.3.3.1}$$

$$\tag{3.3.3.2}$$

$$\frac{\text{1 sandwich}}{\text{2 slices of bread}} = \frac{\text{2 slices of bread}}{\text{1 sandwich}} \tag{3.3.3.3}$$

$$\tag{3.3.3.4}$$

$$\frac{\text{1 sandwich}}{\text{1 slice of cheese}} = \frac{\text{1 slice of cheese}}{\text{1 sandwich}} \tag{3.3.3.5}$$

Step 3) Use these ratios as a **unit conversion** to identify the limiting reagent.

Useful Math Review: Units cancel out just like numbers. If there is a unit in the numerator (on top of the ratio) and the same unit in the denominator (on the bottom of the ratio), they will cancel each other out.

Question 1: Which of my ingredients is the limiting the number of sandwiches I can make? You maybe just did this calculation in your head without even realizing the math that you did.

Use Method A, Method B, and/or Method C to answer question 1.

Method A - Step 3: Identify the Limiting Reagent

Let's use **what we know** and our unit conversion to lead us to what we **want to know**. Never start a math problem with a unit conversion if you don't have to.

What we know:
1) We know we have 40 slices of cheese
2) We know we have 16 slices of bread.

Let's set up equations using the ratios from Step 2 to figure out how much of the other starting material we would need to make our sandwiches.

$$n_{\text{bread needed}} = 40 \text{ slices of cheese} \times \frac{2 \text{ slices of bread}}{1 \text{ slice of cheese}} = 80 \text{ slices of bread} \tag{3.3.3.6}$$

$$\tag{3.3.3.7}$$

$$n_{\text{cheese needed}} = 16 \text{ slices of bread} \times \frac{1 \text{ slice of cheese}}{2 \text{ slices of bread}} = 8 \text{ slices of cheese} \tag{3.3.3.8}$$

These calculations show us that we need 80 slices of bread . . . do we have that many? No.
These calculations show us that we need 16 slices of cheese . . . do we have that many? Yes.

Because we don't have enough bread, bread is considered to be our limiting factor, also known as the **limiting reagent**.

Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We could now move on to Step 4, to answer question 2 and 3.

Method B - Step 3: Identify the Limiting Reagent

From this example you can begin to see what needs to be done to determine which of two reagents, X or Y, is limiting before moving on to the final step of calculating the amount of product you can make.

We must compare the *theoretical* stoichiometric ratio X/Y with the *actual* ratio of amounts of X and Y which were initially mixed together. Whichever ratio is LESS than the theoretical stoichiometric ratio given by the co-efficients in the equation is considered to be the limiting reagent.

In Example 1 this ratio of initial amounts **Actual ratio** (using the materials we actually have)

$\frac{n_{\text{slices of bread (actual)}}}{n_{\text{slices of cheese (actual)}}} = \frac{16 \text{ slices of cheese}}{40 \text{ slices of bread}} = \frac{0.4 \text{ slices of bread}}{1 \text{ slice of cheese}}$ was LESS than the theoretical stoichiometric ratio **Theoretical ratio** (in an ideal world we would have all the materials necessary)

$\text{Theoretical} \left(\frac{1 \text{ slices of bread}}{2 \text{ slices of cheese}}\right) = \frac{0.5 \text{ slice of bread}}{1 \text{ slices of cheese}} \frac{0.4 \text{ slices of bread}}{1 \text{ slice of cheese}} < \frac{0.5 \text{ slice of bread}}{1 \text{ slices of cheese}}$

This indicates that there is not enough bread to react with all the cheese and the bread is the **limiting reagent**. The corresponding general rule, for any reagents X and Y, is

$$\text{If Actual } \frac{\text{X}}{\text{Y}} < \text{Theoretical } \frac{\text{X}}{\text{Y}}, \text{ then X is limiting.} \tag{3.3.3.9}$$

$$\tag{3.3.3.10}$$

$$\text{If Actual } \frac{\text{X}}{\text{Y}} > \text{Theoretical } \frac{\text{X}}{\text{Y}}, \text{ then Y is limiting.} \tag{3.3.3.11}$$

Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We could now move on to Step 4, to answer question 2 and 3.

Method C - Step 3: Identify the Limiting Reagent

These calculations can also be organized as a table, with entries below the respective reactants and products in the chemical equation. We can calculate (hypothetically) how much of each reactant would be required if the other were completely consumed to demonstrate which is in excess, and which is limiting. We use the amount of limiting reagent to calculate the amount of product formed.

Don't forget about the ratios when using the table method.

Option 1: Use all of the cheese

	cheese	+ 2 bread	→ sandwich
Starting material (quantity)	40	16	--
if all cheese is used	-40	-80	n/a
Actual Product (quantity)	0	-64	n/a There can't be a negative amount of something

Option 2: Use all of the bread

	cheese	+ 2 bread	→ sandwich
Starting material (quantity)	40	16	--
if all bread is used	-8	-16	+8
Actual Product (quantity)	32	0	+8

Because Option 2 leaves all of the products with positive numbers, the bread is the **limiting reagent**. Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We can now move on to Step 4, to answer question 2 and 3.

Step 4) Find the answer

Now we can answer question 2 and 3 using the Limiting Reagent that we found using Method A, B or C.

Question 2: Calculate how many sandwiches we can make (must start with limiting reagent)
Answer 2:

$$n_{\text{sandwiches made}} = 16 \text{ slices of bread} \times \frac{1 \text{ sandwich}}{2 \text{ slice of bread}} = 8 \text{ sandwiches} \tag{3.3.3.12}$$

Question 3: When we are finished making sandwiches, how much cheese will be left over? (This is a two-step calculation)

Answer 3:

$$n_{\text{cheese USED}} = 16 \text{ slices of bread} \times \frac{1 \text{ slice of cheese}}{2 \text{ slices of bread}} = 8 \text{ slices of cheese USED} \tag{3.3.3.13}$$

Next, simply subtract how much cheese you used from how much you started with.

$$40 \text{ slices of cheese to START} - 8 \text{ slices of cheese USED} = 32 \text{ slices of cheese left over} \tag{3.3.3.14}$$

A follow up question could be:
Question 4: If I wanted to make sure that I used up all of the left over cheese and make a special trip to the store. How much bread should I get at the store.

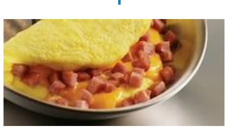
(This calculation would be similar to Question/Answer 2.)

Answer 4:

$$n_{\text{bread needed}} = 32 \text{ slices of cheese} \times \frac{2 \text{ slices of bread}}{1 \text{ slice of cheese}} = 64 \text{ more slices of bread need to be purchased} \tag{3.3.3.15}$$

(Of course, when the actual and theoretical molar ratio of X and Y are equivalent, both reagents will be completely consumed at the same time, and neither is in excess.). Back to top of page

An Example with more than Two Starting Materials



EXAMPLE 2 One of my favorite breakfast foods are ham and cheese omelets in the morning. I am on a diet so I always measure the amount of each ingredient I use. I always make two in case someone else wants one. Below is the recipe for my 'perfect' omelet.

Recipe:
6 Large eggs - 200. g per one egg
1 cup of ham - 125. g per one cup
2 cups of shredded cheese - 50. g per one cup

I open the refrigerator this morning to find an excess of large eggs (50 eggs), 400. g of ham and 250. g of cheese.

Question 1: How many omelets can I make for breakfast with all of the ingredients I pulled out of the refrigerator?

Question 2: What remains when I am done cooking all of the omelets?

Question 3: What is the total mass of our cooked omelets?

Jump to Step 3

Answers

Step 1) Write out the recipe in the form of a balanced equation

	+		+		+		→		+	

6 Large eggs + 2 cups of cheese + 1 cup of ham → 2 omelets

Step 2) Find Quantity (moles) and Identify useful unit conversions and/or **molar ratios**

Unit Conversions

According to the equation written in step 1, these molar ratios can be written by using the number in front of the ingredient, also known as a **co-efficient**.

Once again, when you are first starting out, it is helpful to write the ratios or the stoichiometric ratios connecting all of the components of the recipe.
It makes it easier to pick out which one ratio you will use as a unit conversion to help you calculate what the question is asking.

As you can see, there are more molar ratios this time because there are more starting materials. Additionally, the question gave us information about the mass per unit food item. Therefore there are 8 unit conversions in this question.

$\frac{\text{6 Large eggs}}{\text{2 cups of cheese}} = \frac{\text{2 cups of cheese}}{\text{6 Large eggs}}$	$\frac{\text{6 Large eggs}}{\text{1 cup of ham}} = \frac{\text{1 cup of ham}}{\text{6 Large eggs}}$
$\frac{\text{6 Large eggs}}{\text{2 omelets}} = \frac{\text{2 omelets}}{\text{6 Large eggs}}$	$\frac{\text{2 cups of cheese}}{\text{2 omelets}} = \frac{\text{2 omelets}}{\text{2 cups of cheese}}$
$\frac{\text{2 cups of cheese}}{\text{1 cup of ham}} = \frac{\text{1 cup of ham}}{\text{6 Large eggs}}$	$\frac{\text{1 cup of ham}}{\text{2 omelets}} = \frac{\text{2 omelets}}{\text{1 cup of ham}}$
$\frac{\text{1 cup of ham}}{\text{125 g ham}} = \frac{\text{125 g ham}}{\text{1 cup of ham}}$	$\frac{\text{1 cup of cheese}}{\text{50. g cheese}} = \frac{\text{50. g cheese}}{\text{1 cup of cheese}}$

Find Moles

Then, we need to convert all of the starting materials from **mass** into the **quantity** associated with recipe or equation to be able to compare the starting materials.
The actual quantity of ham and cheese can be calculated using the mass per one unit of material. For instance, in this case, 1 cup of cheese is 50. grams.

In chemistry terms, this is called the **molar mass**. Molar mass can be used as a **unit conversion**. Refer above for useful unit conversions

To relate the idea of molar mass to everyday life is something we do all of the time without even thinking about it.
For instance, you have an assortment of candy in a bucket. Three kids come up to you and ask you for some candy.

Do you weigh the candy and give the three kids equivalent masses? No. That would be unrealistic and probably a little messy.

Instead, we just decide that one candy bar should be given to each kid. Kid #1 receives one Snickers bar, kid #2 receives one Milky Way and kid #3 receives one Kit Kat bar. They are all happy because they received their OWN candy bar; they don't care that one might weigh a little bit more than the other candy bars.

To summarize, Snickers, Milky Way, and Kit Kat all represent ONE candy bar, however they have different masses...but that's okay. To relate it even more to chemistry, one mole of any compound is equivalent to one mole of any other compound, they just have a different mass depending on what substance you are talking about; just substitute these words and you are back to our everyday example; 'mole' = 'candy bar' and 'compound' = 'type of candy bar'.

You can use this idea in reverse, if you know the mass, then the amount of candy bars or 'moles' can be calculated.

$$n_{\text{cheese (actual)}} = 250.\text{ g of cheese} \times \frac{1\text{ cup of cheese}}{50.\text{ g of cheese}} = 5.00\text{ cups of cheese} \tag{3.3.3.16}$$

$$\tag{3.3.3.17}$$

$$n_{\text{ham (actual)}} = 400.\text{ g of ham} \times \frac{1\text{ cup of ham}}{125\text{ g of ham}} = 3.2\text{ cups of ham} \tag{3.3.3.18}$$

Step 3) Find the Limiting Reagent

Jump to Method A, example 2
Jump to Method B, example 2
Jump to Method C, example 2

Method A - Step 3: Identify the Limiting Reagent

Let's use **what we know** and our unit conversion to lead us to what we **want to know**. Never start a math problem with a unit conversion if you don't have to.

What we know:
1) We know we have 5.0 cups of cheese
2) We know we have 3.2 cups of ham.

Let's set up equations using the ratios from Step 2 to figure out how much of the other starting material we would need to make our sandwiches.

$$n_{\text{cheese needed}} = 3.2\text{ cups of ham} \times \frac{2\text{ cups of cheese}}{1\text{ cup of ham}} = 6.4\text{ cups of cheese} \tag{3.3.3.19}$$

$$\tag{3.3.3.20}$$

$$n_{\text{ham needed}} = 5.0\text{ cups of cheese} \times \frac{1\text{ cup of ham}}{2\text{ cups of cheese}} = 2.5\text{ cups of ham} \tag{3.3.3.21}$$

These calculations show us that we need 6.4 cups of cheese . . . do we have that much? No.
These calculations show us that we need 2.5 cups of ham . . . do we have that many? Yes.

Because we don't have enough cheese, cheese is considered to be our limiting factor, also known as the **limiting reagent**.

Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We could now move on to Step 4, to answer Example 2, questions 1, 2, and 3.

Method B - Step 3: Identify the Limiting Reagent

From this example you can begin to see what needs to be done to determine which of two reagents, X or Y, is limiting before moving on to the final step of calculating the amount of product you can make.

Since the eggs, or one starting material is in **excess** it doesn't need to be involved in finding the limiting reagent.
We must compare the *theoretical* stoichiometric ratio X/Y with the *actual* ratio of amounts of X and Y which were initially mixed together. Whichever ratio is LESS than the theoretical stoichiometric ratio given by the co-efficients in the equation is considered to be the limiting reagent.

In Example 1 this ratio of initial amounts **Actual ratio** (using the materials we actually have)

$\frac{n_{\text{cups of cheese (actual)}}}{n_{\text{cups of ham (actual)}}} = \frac{5.0\text{ cups of cheese}}{3.2\text{ cups of ham}} = \frac{1.5625\text{ cups of cheese}}{1\text{ cup of ham}}$ was LESS than the theoretical stoichiometric ratio **Theoretical ratio** (in an ideal world we would have all the materials necessary)

$$\text{Theoretical}\left(\frac{2\text{ cups of cheese}}{1\text{ cup of ham}}\right) = \frac{2.0\text{ cups of cheese}}{1\text{ cup of ham}}\ \frac{1.5625\text{ cups of cheese}}{1\text{ cup of ham}} < \frac{2.0\text{ cups of cheese}}{1\text{ cup of ham}}$$

This indicates that there is not enough cups of cheese to react with all the ham and the cheese is the **limiting reagent**. The corresponding general rule, for any reagents X and Y, is

$$\text{If Actual } \frac{\mathrm{X}}{\mathrm{Y}} < \text{Theoretical } \frac{\mathrm{X}}{\mathrm{Y}}, \text{ then X is limiting.} \tag{3.3.3.22}$$

$$\tag{3.3.3.23}$$

$$\text{If Actual } \frac{\mathrm{X}}{\mathrm{Y}} > \text{Theoretical } \frac{\mathrm{X}}{\mathrm{Y}}, \text{ then Y is limiting.} \tag{3.3.3.24}$$

Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We could now move on to Step 4, to answer Example 2, questions 1, 2, and 3.

Method C - Step 3: Identify the Limiting Reagent

These calculations can also be organized as a table, with entries below the respective reactants and products in the chemical equation. We can calculate (hypothetically) how much of each reactant would be required if the other were completely consumed to demonstrate which is in excess, and which is limiting. We use the amount of limiting reagent to calculate the amount of product formed.

Note: Don't forget about the ratios when using the table method.

Option 1: Use all of the ham

	6 eggs	+ 1 cup of ham	+ 2 cups of cheese	→ 2 omelets
Starting material (quantity)	50	5	3.2	-
if all ham is used	-30	-5	-6.4	n/a
Actual Product (quantity)	20	0	-3.2	n/a There can't be a negative amount of something

Option 2: Use all of the cheese

	6 eggs	+ 1 cup of ham	+ 2 cups of cheese	→ 2 omelets
Starting material (quantity)	50	5	3.2	-
if all cheese is used	-19.2	-1.6	-3.2	n/a
Actual Product (quantity)	30.8	3.4	0	3.2

Option 3: Use all of the bread

	6 eggs	+ 1 cup of ham	+ 2 cups of cheese	→ 2 omelets
Starting material (quantity)	50	5	3.2	-
if all cheese is used	-50	-8.3	-16.7	n/a
Actual Product (quantity)	0	-3.3	-13.5	n/a There can't be a negative amount of something

Because Option 2 leaves us with all positive numbers, the cheese is the **limiting reagent**. Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We can now move on to Step 4, to answer Example 2, questions 1, 2, and 3.

Step 4) Find the answer

Now we can answer Example 2, questions 1 2 and 3 using the Limiting Reagent that we found using Method A, B or C.

Question 1: How many omelets can I make for breakfast with all of the ingredients I pulled out of the refrigerator? (Start with limiting reagent)

Answer 1:

$$n_{\text{omelets made}} = 5.0 \text{ cups of cheese} \times \frac{2 \text{ omelets}}{2 \text{ cups of cheese}} = 5 \text{ omelets} \tag{3.3.3.25}$$

Question 2: What remains when I am done cooking the omelets? (This is a two-step calculation)

Answer 2:

$$n_{\text{ham USED}} = 5.0 \text{ cups of cheese} \times \frac{1 \text{ cup of ham}}{2 \text{ cups of cheese}} = 2.5 \text{ cups of ham USED} \tag{3.3.3.26}$$

$$n_{\text{eggs USED}} = 5.0 \text{ cups of cheese} \times \frac{6 \text{ Large eggs}}{2 \text{ cups of cheese}} = 15 \text{ Large eggs USED} \tag{3.3.3.27}$$

Next, simply subtract how much ham and eggs you used from how much you started with.

$$3.2 \text{ cups of ham to START} - 2.5 \text{ cups of ham USED} = 0.7 \text{ cups of ham left over} \tag{3.3.3.28}$$

$$50 \text{ Large eggs to START} - 15 \text{ Large eggs USED} = 35 \text{ Large eggs left over} \tag{3.3.3.29}$$

Question 3: What is the total weight of one omelet

Answer 3: Use the answer to Question 1 in order to start this problem.

$$\text{Mass of all omelets} = 5.0 \text{ omelets} \times \frac{(1200 \text{ g of egg} + 125 \text{ g. of ham} + 100. \text{ g of cheese})}{2 \text{ omelets}} = 3562.5 \text{ g of omelets} \tag{3.3.3.30}$$

A follow up question could be:

Question 4: How much does one omelet weigh?

(This calculation would be similar to the **molar mass** explained above.)

Answer 4:

$$\text{Mass of one omelet} = \frac{3562.5 \text{ g of omelet}}{5 \text{ omelets}} = 712.5 \text{ g per one omelet} \tag{3.3.3.31}$$

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Example 3 - Relating Real World examples to Chemical Equations

Ore hematite

Pure Coke (carbon source)

Ore hematite, Fe_2O_3, is the chief iron ore used in production of iron metal.

Reacting the ore hematite (Fe_2O_3) with coke (C) produces iron metal (Fe) and CO_2. As manager of a blast furnace you are told that you have 20.5 Mg (megagrams) of Fe_2O_3 and 2.84 Mg of coke on hand. (a) Which should you order first—another shipment of iron ore or one of coke? (b) How many megagrams of iron can you make with the materials you have?

If you get stuck, go back to Example 2 and review each step using terms you are familiar with. You will use the exact same process and calculation to solve Example 3 as you used in Example 2.

Answer

Step 1

Write a balanced equation 2 $Fe_2O_{3\,(s)}$ + 3 $C_{(s)}$ → 3 $CO_{2\,(g)}$ + 4 $Fe_{(s)}$

Step 2

Find Moles and Identify useful Unit Conversions

The initial amounts of C and Fe_2O_3 are calculated using appropriate molar masses found on the periodic table

$$n_{\text{Carbon (actual)}} = 2.84 \times 10^6 \text{g C} \times \frac{1 \text{ mol C}}{12.01 \text{ g C}} = 2.36 \times 10^5 \text{mol C} \tag{3.3.3.32}$$

$$\tag{3.3.3.33}$$

$$n_{\text{Fe}_2\text{O}_3 \text{ (actual)}} = 20.5 \times 10^6 \text{g Fe}_2\text{O}_3 \times \frac{1 \text{ mol Fe}_2\text{O}_3}{159.69 \text{ g Fe}_2\text{O}_3} = 1.28 \times 10^5 \text{mol Fe}_2\text{O}_3 \tag{3.3.3.34}$$

The stoichiometric ratio connecting C and Fe_2O_3 is

$\frac{3 \text{ mol C}}{2 \text{ mol Fe}_2\text{O}_3} = \frac{2 \text{ mol Fe}_2\text{O}_3}{3 \text{ mol C}}$ Compare to Step 2 in the Omelet Example

Step 3

Find the **limiting reagent**

Jump to Method B
Jump to Method C

Method A

Let's use **what we know** and our unit conversion to lead us to what we **want to know**. Never start a math problem with a unit conversion if you don't have to.

What we know:
1) We know we have 1.28 x 10^5 mol of Fe_2O_3
2) We know we have 2.36 x 10^5 mol C.

Let's set up equations using the the ratio from Step 2 to figure out how much of the other starting material we would need to make our sandwiches.

$$n_{\text{Carbon needed}} = 1.28 \times 10^5 \text{ mol Fe}_2\text{O}_3 \times \frac{3 \text{ mol C}}{2 \text{ mol Fe}_2\text{O}_3} = 1.92 \times 10^5 \text{ mol C needed} \tag{3.3.3.35}$$

$$\tag{3.3.3.36}$$

$$n_{\text{Fe}_2\text{O}_3 \text{ needed}} = 2.36 \times 10^5 \text{ mol C} \times \frac{2 \text{ mol Fe}_2\text{O}_3}{3 \text{ mol C}} = 1.57 \times 10^5 \text{ mol Fe}_2\text{O}_3 \text{ needed} \tag{3.3.3.37}$$

These calculations show us that we need 1.92 x 10^5 mol C . . . do we have that ? Yes. We have 2.36 x 10^5 mol C
These calculations show us that we need 1.57 x 10^5 mol Fe_2O_3 . . . do we have that? No. We only have 1.28 x 10^5 mol Fe_2O_3

Because we don't have enough Fe_2O_3, Fe_2O_3 is considered to be our limiting factor, also known as the **limiting reagent**.

Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction. We could now move on to Step 4, to answer Question 1 and 2.

Method B

Their ratio is

$\frac{n_{\text{C}}(\text{actual})}{n_{\text{Fe}_2\text{O}_3}(\text{actual})} = \frac{2.36 \times 10^5 \text{mol C}}{1.28 \times 10^5 \text{mol Fe}_2\text{O}_3} = \frac{1.84 \text{ mol C}}{1 \text{ mol Fe}_2\text{O}_3}$ was MORE than the **Theoretical** stoichiometric ratio
$\text{Theoretical} \left(\frac{3 \text{ C}}{2 \text{ Fe}_2\text{O}_3}\right) = \frac{1.5 \text{ mol C}}{1 \text{ mol Fe}_2\text{O}_3} \; \frac{1.84 \text{ mol C}}{1 \text{ mol Fe}_2\text{O}_3} > \frac{1.5 \text{ mol C}}{1 \text{ mol Fe}_2\text{O}_3}$

This indicates that there is not enough Fe_2O_3 to react with all of the carbon (C). Therefore Fe_2O_3 is the **limiting reagent**.

In other words, you have more than enough C to react with all the Fe_2O_3. Fe_2O_3 is the limiting reagent, and you will want to order more of it **first** since it will be consumed first.

The corresponding general rule, for any reagents X and Y, is

$$\text{If Actual } \frac{\text{X}}{\text{Y}} < \text{Theoretical } \frac{\text{X}}{\text{Y}}, \text{ then X is limiting.} \tag{3.3.3.38}$$

$$\tag{3.3.3.39}$$

$$\text{If Actual } \frac{\text{X}}{\text{Y}} > \text{Theoretical } \frac{\text{X}}{\text{Y}}, \text{ then Y is limiting.} \tag{3.3.3.40}$$

We could now move on to Step 4, to answer Question 1 and 2.

Method C

$2 \; Fe_2O_{3\,(s)} + 3 \; C_{(s)} \rightarrow 3 \; CO_{2\,(g)} + 4 \; Fe_{(s)}$

Option 1: Use all of the iron (III) oxide

	2 $Fe_2O_{3\,(s)}$	**+ 3 $C_{(s)}$**	**→ 3 $CO_{2\,(g)}$**	**+ 4 $Fe_{(s)}$**
Starting material (mol)	1.28 x 10^5	2.36 x 10^5	--	--
if all Fe_2O_3 is used	-1.28 x 10^5	-1.92 x 10^5	+1.92 x 10^5	+2.56 x 10^5

Actual Product (quantity)	0	4.40 x 10^4	1.92 x 10^5	2.56 x 10^5

Option 2: Use all of the carbon

	2 Fe_2O_3 $_{(s)}$	**+ 3 C $_{(s)}$**	**→ 3 CO_2 $_{(g)}$**	**+ 4 Fe $_{(s)}$**
Starting material (mol)	1.28 x 10^5	2.36 x 10^5	--	--
if all carbon is used	-1.57 x 10^5	-2.36 x 10^5	+2.36 x 10^5	+3.15 x 10^5
Actual Product (quantity)	-2.9 x 10^4	0	**n/a** Amounts cannot be negative	

Because Option 1 leaves all of the amounts with positive numbers, the Fe_2O_3 is the **limiting reagent**. Once the limiting reagent is identified, only the initial amount of the limiting reagent can be used to start any calculations regarding this reaction.

Step 4

b) The amount of product formed in a reaction may be calculated via an appropriate stoichiometric ratio from the amount of a reactant which was *consumed*. Some of the excess reactant C will be left over, but all the initial amount of Fe_2O_3 will be consumed. Therefore we use the actual $n_{\mathrm{Fe_2O_3}}$ to calculate how much Fe can be obtained

Four general steps:
Step 1) Write and equation
Step 2) Find moles
Step 3) Use molar ratio to identify limiting reagent
Step 4) Convert to the answer.

$$m_{\mathrm{Fe_2O_3}} \xrightarrow{divide M_{\mathrm{Fe}}} n_{\mathrm{Fe_2O_3}} \xrightarrow{times\,(\mathrm{Fe/Fe_2O_3})} n_{\mathrm{Fe}} \xrightarrow{times M_{\mathrm{Fe}}} m_{\mathrm{Fe}} \quad n_{\mathrm{mol\ Fe}} = 1.28 \times 10^5\ \mathrm{mol\ Fe_2O_3} \times \frac{4\ \mathrm{mol\ Fe}}{2\ \mathrm{mol\ Fe_2O_3}} = 2.56 \times 10^5\ \mathrm{mol\ Fe}$$

$$m_{\mathrm{\ g\ Fe}} = 2.56 \times 10^5\ \mathrm{mol\ Fe} \times \frac{55.85\ \mathrm{g}}{1\ \mathrm{mol\ Fe}} = 1.43 \times 10^7\ \mathrm{g\ Fe}$$

We will make 1.43 × 10^6 g Fe, or 14.3 Mg, Fe with this amount of reagents.
Compare to Step 4 in the Omelet Example
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Let's Practice!

Check out these simulations to help you with this concept. Follow the four steps below.

1) Write a BALANCED chemical equation. The equation in the simulation is not balanced.
2) Choose two starting masses for your starting materials.
3) Work through the steps to calculate how much of each product will be left.
4) Work through the steps to calculate how much of a reactant will be left once the reaction is complete.
5) Click "Run Trial" to check if you are right!

Methane and Oxygen - Limiting Reagent Practice
Silver nitrate and Iron(III) chloride Limiting Reagent Practice
Aluminum and Copper(II) chloride - Limiting Reagent Practice
Sodium phosphate and Tin (IV) nitrate - Limiting Reagent Practice

As you can see from all of these examples, in a case where there is a limiting reagent, *the initial amount of the limiting reagent must be used to calculate the amount of product formed*. Using the initial amount of a reagent present in excess would be **incorrect**, because such a reagent is not entirely consumed.

The concept of a limiting reagent was used by the nineteenth century German chemist Justus von Liebig (1807 to 1873) to derive an important biological and ecological law. **Liebig's law of the minimum** states that the essential substance available in the smallest amount relative to some critical minimum will control growth and reproduction of any species of plant or animal life. When a group of organisms runs out of that essential limiting reagent, the chemical reactions needed for growth and reproduction must stop. Vitamins, protein, and other nutrients are essential for growth of the human body and of human populations. Similarly, the growth of algae in natural bodies of water such as Lake Erie can be inhibited by reducing the supply of nutrients such as phosphorus in the form of phosphates. It is for this reason that many states have regulated or banned the use of phosphates in detergents and are constructing treatment plants which can remove phosphates from municipal sewage before they enter lakes or streams.

Example 4 from Equations and Mass Relationships also illustrates the idea that one reactant in a chemical equation may be completely consumed without using up all of another. In the laboratory as well as the environment, inexpensive reagents like atmospheric O_2 are often supplied in excess. Some portion of such a reagent will be left unchanged after the reaction. Conversely, at least one reagent is usually completely consumed. When it is gone, the other excess reactants have nothing to react with and they cannot be converted to products. The substance which is used up first is the **limiting reagent**.

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