Science Objectives

- Students will write mole ratios from balanced chemical equations.
- Students will use mole-to-mass conversion to determine mass of reactants and products given the number of moles.
- Students will calculate the number of moles and the mass of a reactant or product when given the number of moles or the mass of another reactant or product using the balanced chemical equations.
- Students will list the steps used in solving stoichiometric problems.

Vocabulary

- mole
- mole ratio
- mole-to-mass conversion
- mass-to-mole conversion
- molar mass
- combustion
- reactant
- product

About the Lesson

- This lesson involves students using a simulation of three combustion reactions to develop skills necessary to solve stoichiometric problems.
- Students will use the combustion of methane to analyze mole ratios in chemical reactions.
- Students will the use the combustion of propane to analyze mole to mass conversion.
- Finally, students will use the combustion of propane to analyze mass to mole conversion.
- As a result, students will:
    - Reinforce the skills of balancing chemical equations
   - Develop a method of solving stoichiometry problems

TI-Nspire™ Navigator™

- Send out the *Solving_Stoichiometry_Problems.tns* file.
- Monitor student progress using Class Capture.
- Use Live Presenter to allow students to show how they manipulate variables that effect results.

Activity Materials

- Compatible TI Technologies: TI-Nspire™ CX Handhelds, TI-Nspire™ Apps for iPad®, TI-Nspire™ Software
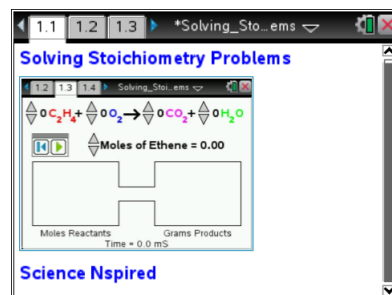
Tech Tips:

- This activity includes screen captures taken from the TI-Nspire CX handheld. It is also appropriate for use with the TI-Nspire family of products including TI-Nspire software and TI-Nspire App. Slight variations to these directions may be required if using other technologies besides the handheld.
- Watch for additional Tech Tips throughout the activity for the specific technology you are using.
- Access free tutorials at http://education.ti.com/calculators/pd/US/Online-Learning/Tutorials

Lesson Files:
Student Activity

- Solving_Stoichiometry_ Problems_Student.doc
- Solving_Stoichiometry_ Problems _Student.pdf
- Solving_Stoichiometry_ Problems.tns

Discussion Points and Possible Answers

Have students answer all questions on their activity sheet.

Move to page 1.2.

Have students answer questions 1-11 before moving to page 1.3.

In this part of the activity students will analyze mole ratios.

1. Students are to read the directions on how to use the simulation. When finished, they can select ☒ to close the directions. If needed at any time during the simulation, students can select [menu] if they would like to view the directions again.
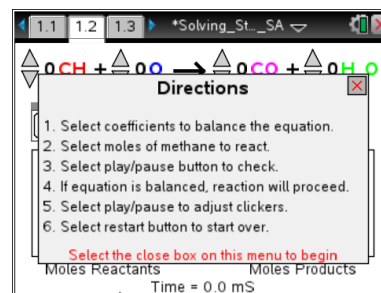
> 👆**Tech Tip:** To view the directions again, students should select 🔧 >
> **Stoichiometric Problems > Directions**. They may need to back-out to the
> main Tools Menu 🔧 to see the desired menu option.

2. First students need to balance the equation using the up and down arrows to adjust the coefficients that appear in front of each reactant and product.

Q1.   Record the balanced equation: _____

      Answer: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

3. Select the up arrow to change the number of moles of methane to be used in the reaction. Then, select play ▶.

Q2.   Select four different amounts of methane. For each amount, record the moles of reactants and products in the table below.

    Sample Answers:

Moles of Methane	Moles of Oxygen	Moles of Carbon Dioxide	Moles of Water
0.20	0.40	0.20	0.40
0.50	1.0	0.5	1.0
1.0	2.0	1.0	2.0
1.5	3.0	1.5	3.0

Q3.   How many moles of water are produced for 0.30 mole of methane? What is the mole ratio?

Answer: 0.6 moles of H_2O for 0.3 mole of CH_4

Q4.   How many moles of water are produced for every mole of methane? What is the mole ratio?

Answer: 2 moles of H_2O for every mole of CH_4

> **Teacher Tip:** Remind students that in this part of the activity they should use 2 significant figures for all calculations.

Q5.   How many moles of water are produced for 2.0 moles of methane? For any given number of moles of methane?

Answer: 4.0 moles of H_2O for 2.0 moles of CH_4. Using coefficients in the balanced equations,

$\text{Moles } H_2O = 2.0 \text{ moles } CH_4 \times \dfrac{2 \text{ moles } H_2O}{1 \text{ mole } CH_4} = 4.0 \text{ moles } H_2O$. For any given number of moles of

methane, use the mole ratio of water and methane as a conversion factor.

Q6.   How many moles of oxygen are consumed to produce 1.5 moles of carbon dioxide?

Answer: 3.0 moles of O_2 for 1.5 moles of CO_2

Q7.   How many moles of oxygen are consumed for every mole of carbon dioxide?

Answer: 2 moles of O_2 for every mole of CO_2

Q8.   How many moles of oxygen are consumed to produce 3.2 mole of carbon dioxide? How many are consumed to produce any given number of moles of carbon dioxide?

Answer: $\text{Moles } O_2 = 3.2 \text{ moles } CO_2 \times \dfrac{2 \text{ moles } O_2}{1 \text{ mole } CO_2} = 6.4 \text{ moles } O_2$. To produce any given number

of moles of carbon dioxide, use the mole ratio of oxygen and carbon dioxide as a conversion factor.

Q9.   What do mole ratios tell us?

Answer: The mole ratio provides the ratio of the moles of one reactant or product to the moles of another reactant or product in the balanced equation for a chemical reaction. Mole ratios are conversion factors that can be used to relate:

1. moles of product formed from a certain number of moles of reactant
2. moles of reactant needed to form a certain number of moles of a product.
3. the number of moles of a particular reactant needed to completely react with a certain number of moles of a second reactant.

Q10. How do you calculate the mole ratios?

Answer: The coefficients in a balanced chemical equation can be used to determine the relative number of moles of a compound involved in a chemical reaction.

Q11. Write all mole ratios for a given reaction.

Answer: the following mole ratios can be written: $\dfrac{1 \text{ mole } CH_4}{2 \text{ moles } O_2}$, $\dfrac{1 \text{ mole } CH_4}{1 \text{ mole } CO_2}$, $\dfrac{1 \text{ mole } CH_4}{2 \text{ moles } H_2O}$,

$\dfrac{1 \text{ mole } CH_4}{1 \text{ mole } CO_2}$, $\dfrac{1 \text{ mole } CH_4}{2 \text{ moles } H_2O}$, $\dfrac{2 \text{ moles } O_2}{1 \text{ mole } CO_2}$, $\dfrac{2 \text{ moles } O_2}{2 \text{ moles } H_2O}$, $\dfrac{1 \text{ mole } CO_2}{2 \text{ moles } H_2O}$, and the inverses of each of these ratios.

> **Teacher Tip:** Encourage students to analyze each problem and determine what type of ratio they need to use in order to find unknown amounts of reactants or products.

Move to page 1.3.
Have students answer questions 12-19 before moving to page 1.3.

In this part of the activity students will use the simulation to determine that mole to mass conversion is necessary to calculate the mass of products for a given amount of reactants in moles. They should use three significant figures for all calculations in this part of the activity.
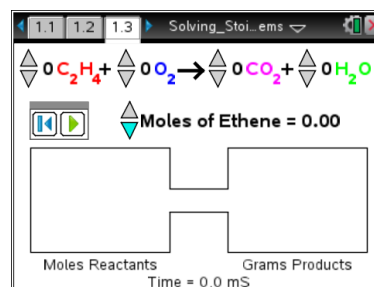
4. Students are to balance the given equation. They can use the up and down arrows to adjust the coefficients that appear in front of each reactant and product.

Q12. Record the balanced equation: _____

Answer: $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

5. Students will now set the number of moles of ethene equal to 1.00 and then select ▶.

> **Teacher Tip:** Remind students that in this part of the activity they should use 3 significant figures for all calculations.

Q13. How many moles of carbon dioxide will be produced in this reaction? Support your answer using the appropriate mole ratio.

Answer: Moles $CO_2 = 1.00$ mole $C_2H_4 \times \dfrac{2 \text{ moles } CO_2}{1 \text{ mole } C_2H_4} = 2.00$ moles CO_2

Q14. How many grams of carbon dioxide will be produced in this reaction? Support your answer using the appropriate molar mass.

Answer: molar mass of CO_2 is $12.0 + 16.0 \times 2 = 44.0$ g/mole, 2 moles $\times$ 44.0 g/mole = 88.0 g

Q15. How many moles of water will be produced in this reaction? Support your answer using the appropriate mole ratio.

Answer: Moles $H_2O = 1.00$ mole $C_2H_4 \times \dfrac{2 \text{ moles } H_2O}{1 \text{ mole } C_2H_4} = 2.00$ moles H_2O

Q16. How many grams of water will be produced in this reaction? Support your answer using the appropriate molar mass.

Answer: molar mass of H_2O is $2.0 + 16.0 = 18.0$ g/mole, 2 moles $\times$ 18.0 g/mole = 36.0 g

6. Students are to enter their calculated answers in the appropriate text boxes. If necessary, they should revise their calculations.

7. Then students will reset the simulation. They can select the up or down arrows to change the number of moles of ethene to be used in the reaction.
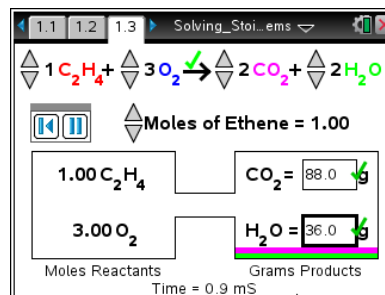
> **Tech Tip:** Students will need to tap in the grams box to bring up the keyboard to input answers. Press and hold down the key that hides the keyboard – and choose split -- to see behind the keyboard. You can then use the same key to slide the split keyboard up and down.

7. Select three different amounts of ethene and calculate the moles and the mass of the products. Show your calculations and results in the table below. Verify your calculations using simulation.

__Sample Answers__:

Moles of C_2H_4	Calculations	Grams of CO_2	Grams of H_2O
2.00	2.00 moles of $C_2H_4 \times \dfrac{2 \text{ moles } CO_2}{1 \text{ mole } C_2H_4} = 4.00$ moles of CO_2 4.00 moles of $CO_2 \times 44.0 \dfrac{g}{\text{mole}} = 176$ g of CO_2 2.00 moles of $C_2H_4 \times \dfrac{2 \text{ moles } H_2O}{1 \text{ mole } C_2H_4} = 4.00$ moles of H_2O 4.00 moles of $H_2O \times 18.0 \dfrac{g}{\text{mole}} = 72.0$ g of H_2O	176 g	72.0 g
5.00	5.00 moles of $C_2H_4 \times \dfrac{2 \text{ moles } CO_2}{1 \text{ mole } C_2H_4} = 10.0$ moles of CO_2 10.0 moles of $CO_2 \times 44.0 \dfrac{g}{\text{mole}} = 440$ g of CO_2 5.00 moles of $C_2H_4 \times \dfrac{2 \text{ moles } H_2O}{1 \text{ mole } C_2H_4} = 10.0$ moles of H_2O 10.0 moles of $H_2O \times 18.0 \dfrac{g}{\text{mole}} = 180$ g of H_2O	440 g	180 g
8.00	8.00 moles of $C_2H_4 \times \dfrac{2 \text{ moles } CO_2}{1 \text{ mole } C_2H_4} = 16.0$ moles of CO_2 16.0 moles of $CO_2 \times 44.0 \dfrac{g}{\text{mole}} = 704$ g of CO_2	704 g	288 g

$$8.00 \text{ moles of } C_2H_4 \times \frac{2 \text{ moles } H_2O}{1 \text{ mole } C_2H_4} = 16.0 \text{ moles of } H_2O$$

$$16.0 \text{ moles of } H_2O \times 18.0 \frac{g}{\text{mole}} = 288 \text{ g of } H_2O$$

Q18. How many grams of water and carbon dioxide are produced if 0.700 moles of ethene is burned?

Answer: Find the number of moles of CO_2 and H_2O using appropriate mole ratios, and then use molar mass of each product to convert from moles to mass.

$$0.700 \text{ moles } C_2H_4 \times \frac{2 \text{ moles } CO_2}{1 \text{ mole } C_2H_4} = 1.40 \text{ moles } CO_2 \text{ , } 1.40 \text{ moles} \times 44.0 \text{ g/mole} = 61.6 \text{ g of } CO_2$$

$$0.700 \text{ moles } C_2H_4 \times \frac{2 \text{ moles } H_2O}{1 \text{ mole } C_2H_4} = 1.40 \text{ moles } H_2O \text{ , } 1.40 \text{ moles} \times 18.0 \text{ g/mole} = 25.2 \text{ g of } H_2O$$

Q19. How many grams of water and carbon dioxide are produced if 4.00 moles of oxygen is consumed?

Answer: Find the number of moles of CO_2 and H_2O using appropriate mole ratios, and then use molar mass to convert from moles to mass.

$$4.00 \text{ moles } O_2 \times \frac{2 \text{ moles } CO_2}{3 \text{ moles } O_2} = 2.67 \text{ moles } CO_2 \text{ , } 2.67 \text{ moles} \times 44.0 \text{ g/mole} = 118 \text{ g of } CO_2$$

$$4.00 \text{ moles } O_2 \times \frac{2 \text{ moles } H_2O}{3 \text{ moles } O_2} = 2.67 \text{ moles } O_2 \text{ , } 2.67 \text{ moles} \times 18.0 \text{ g/mole} = 48.1 \text{ g of } O_2$$

Tech Tip: Students can insert a *Calculator* page to complete calculations for the problems by selecting [ctrl] [doc ▾] and selecting Add Calculator. They can also use the Scratchpad [▦].

Tech Tip: Students can insert a *Calculator* page by selecting ✚ > **Calculator**.

Move to page 1.4.

In this part of the activity students will use the simulation to calculate the mass of products given the mass of reactants in the combustion of propane combustion reaction. They should use three significant figures for all calculations in this part of the activity. Based on their work, they will determine the key steps to solving stoichiometry problems.

8. First students are to balance the equation. Use the up and down arrows to adjust the coefficients that appear in front of each reactant and product.

Q20. Record the balanced equation: _____

Answer: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

9. Now students are to set the mass of propane equal to 10.0 g and then select the play button [▶].

> **Teacher Tip:** Remind students that in this part of the activity they should use 3 significant figures for all calculations.

Q21. How many moles of propane are used in this reaction? Show your calculations.

Answer: $10.0 \text{ grams of } C_3H_8 \times \dfrac{1 \text{ mole}}{44.1 \text{ grams}} = 0.227 \text{ moles of } C_3H_8$

Q22. How many moles of carbon dioxide will be produced in this reaction? Show your calculations.

Answer: $\text{Moles } CO_2 = 0.227 \text{ moles } C_3H_8 \times \dfrac{3 \text{ moles } CO_2}{1 \text{ mole } C_3H_8} = 0.681 \text{ moles } CO_2$

Q23. How many grams of carbon dioxide will be produced in this reaction? Show your calculations.

Answer: 0.681 moles × 44.0 g/mole = 30.0 g

Q24. How many moles of water will be produced in this reaction? Show your calculations.

**Answer:** Moles $H_2O = 0.227$ moles $C_3H_8 \times \dfrac{4 \text{ moles } H_2O}{1 \text{ mole } C_3H_8} = 0.908$ moles H_2O

Q25. How many grams of water will be produced in this reaction? Show your calculations.

Answer: 0.908 moles × 18.0 g/mole = 16.3 g

10. Students are to enter their calculated answers in the appropriate text boxes. If necessary, they should revise their calculations.

11. Then students will reset the simulation. They can select the up or down arrows to change the mass of propane to be used in the reaction.
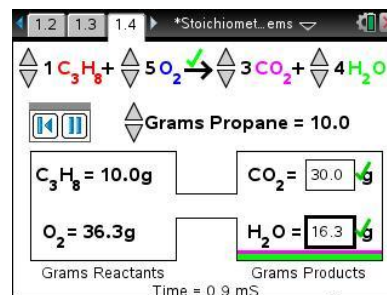
Q26. Select two different values and calculate the moles and mass of the products. Show your calculations and results in the table below. Verify your calculations using the simulation.

Grams of C_3H_8	Calculations	Grams of CO_2	Grams of H_2O
30.0	30.0 grams of $C_3H_8 \times \dfrac{1 \text{ mole}}{44.1 \text{ grams}} = 0.680$ moles of C_3H_8 0.680 moles $C_3H_8 \times \dfrac{3 \text{ moles } CO_2}{1 \text{ mole } C_3H_8} = 2.040$ moles of CO_2 2.040 moles of $CO_2 \times 44.0 \dfrac{g}{mole} = 89.8$ g of CO_2 0.680 moles of $C_3H_8 \times \dfrac{4 \text{ moles } H_2O}{1 \text{ mole } C_3H_8} = 2.72$ moles of H_2O 2.72 moles of $H_2O \times 18.0 \dfrac{g}{mole} = 49.0$ g of H_2O	89.8 g	49.0 g

50.0	50.0 grams of $C_3H_8 \times \dfrac{1 \text{ mole}}{44.1 \text{ grams}} = 1.13$ moles of C_3H_8 1.13 moles of $C_3H_8 \times \dfrac{3 \text{ moles } CO_2}{1 \text{ mole } C_3H_8} = 3.39$ moles of CO_2 3.39 moles of $CO_2 \times 44.0 \dfrac{g}{\text{mole}} = 149$ g of CO_2 1.13 moles of $C_3H_8 \times \dfrac{4 \text{ moles } H_2O}{1 \text{ mole } C_3H_8} = 4.52$ moles of H_2O 4.52 moles of $H_2O \times 18.0 \dfrac{g}{\text{mole}} = 81.4$ g of H_2O	149 g	81.4 g

Q27. How many grams of water and carbon dioxide are produced if 25.0 grams of propane is burned?

Answer: Use propane's molar mass to find the number of moles of propane used in the reaction. Find the number of moles CO_2 and H_2O using appropriate mole ratios, and then use the molar mass of each product to convert from moles to mass.

25.0 grams of $C_3H_8 \times \dfrac{1 \text{ mole}}{44.1 \text{ grams}} = 0.567$ moles of C_3H_8

0.567 moles of $C_3H_8 \times \dfrac{3 \text{ moles } CO_2}{1 \text{ mole } C_3H_8} = 1.70$ moles of CO_2

1.70 moles $\times 44.0$ g/mole $= 74.8$ g of CO_2

0.567 moles of $C_3H_8 \times \dfrac{4 \text{ moles } H_2O}{1 \text{ mole } C_2H_4} = 2.27$ moles of H_2O

2.27 moles $\times 18.0$ g/mole $= 40.9$ g of H_2O

Q28. How many grams of propane and oxygen were used if it resulted in 50.0 grams of water?

> **Answer:** Use water molar mass to find the number of moles of water produced in the reaction. Find the number of moles C_3H_8 and O_2 using appropriate mole ratios, and then use the molar mass of each reactant to convert from moles to mass.
>
> $$50.0 \text{ grams of } H_2O \times \frac{1 \text{ mole}}{18.0 \text{ grams}} = 2.78 \text{ moles of } H_2O$$
>
> $$2.78 \text{ moles of } H_2O \times \frac{1 \text{ mole } C_3H_8}{4 \text{ moles } H_2O} = 0.695 \text{ moles of } C_3H_8$$
>
> $0.695 \text{ moles of } C_3H_8 \times 44.1 \text{ g/mole} = 30.6 \text{ g of } C_3H_8.$
>
> $$2.78 \text{ moles of } H_2O \times \frac{5 \text{ moles } O_2}{4 \text{ moles } H_2O} = 3.48 \text{ moles of } O_2$$
>
> $3.48 \text{ moles of } O_2 \times 32.0 \text{ g/mole} = 111 \text{ g of } O_2$

Q29. Describe the ordered sequence of key steps necessary to calculate the number of moles and the mass of a reactant or product when given the number of moles or the mass of another reactant or product.

> **Sample Answer:**
> 1. Balance the equation.
> 2. Use the molar mass to convert from grams to moles.
> 3. Use the mole ratios to find the moles of unknown reactants and/or products.
> 4. Use molar mass to convert from moles to grams.

TI-Nspire Navigator Opportunities

Allow students to volunteer to be the Live Presenter and demonstrate how to use simulation to determine the moles and/or mass of products of reaction given mole and/or mass of reactants. Use Quick Poll to check for understanding during the course of the activity.

Wrap Up

When students are finished with the activity, discuss the four steps used to solve various stoichiometric problems.

Assessment

- Answers to questions are written into the student worksheet.
- Use Quick Poll to collect answers to questions given in the student worksheet.