

**Teacher’s Guide**

**Chemistry Takes to the Skies**

***February 2020***

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Activate students’ prior knowledge and engage them before they read the article.

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These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer 5](#_Graphic_Organizer)

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 9](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

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# Anticipation Guide

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. World War I pilots used skywriting to communicate with one another. |
|  |  | 1. Skywriting is created with smoke. |
|  |  | 1. The gaseous products expelled from the exhaust pipe of a jet are white. |
|  |  | 1. Contrails and skywriting are chemically the same. |
|  |  | 1. Jet fuel has a higher boiling point than gasoline. |
|  |  | 1. Smoke is an aerosol, with solid or liquid particles suspended in air. |
|  |  | 1. Words written with skywriting remain legible for 3-4 hours. |
|  |  | 1. When the letters from skywriting dissipate, the particles evaporate. |
|  |  | 1. There are thousands of experienced skywriters in the world today. |
|  |  | 1. A nanometer is larger than a micrometer. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. Classify each of the following as either chemical or physical processes. For each, explain your answer.
   1. Combustion
   2. Fractional distillation
2. Examine the figure on page 13 and answer the following questions.
   1. What is distillation?
   2. Why is the process in this figure called fractional distillation?
   3. Why must crude oil go through this process in order to be useful?
   4. Describe the relationship between molecular mass, density, and boiling point for hydrocarbons.
   5. Use molecule structure to explain the relationship between molecular mass and boiling point.
3. If there are seven carbons in an alkane, then what is its molecular formula? Write the balanced chemical equation for the combustion of this seven-carbon compound.
4. What is the molecular mass of kerosene?
5. When we see a contrail in the sky, it is not the water vapor from the combustion reaction that we see. Explain what happens to allow us to see this contrail.
6. Would you expect a contrail to last longer on a humid day or a dry day (assuming the same temperature)? Explain.
7. An aerosol is one subcategory of a colloid. Colloids have particles of one substance with a size between 1 and 1000 nm dispersed in another substance. Each part of this mixture can be of any phase and the phase combination is what classifies them into their subcategories. Use the table and the figure on page 14 to answer the questions below:

How many nanometers are in a micrometer?

* 1. How many nanometers are in a kilometer?
  2. How many nanometers are in a millimeter?

**Student Reading Comprehension Questions, cont.**

1. Why don’t skywriters simply rely on contrails to do their writing, rather than adding in other substances?
2. Why do contrails and the smoke from skywriting dissipate fairly quickly, even on a day without any wind?

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Which would make more water when combusted in oxygen, 1 mole of C10H22 or 1 mole of C15H32? Explain, but do not use calculations.
2. To what total volume will the water vapor from the combustion of 1.00 liter of kerosene spread when released in the atmosphere at 30,000 feet, where the temperature is -47.8oC and the pressure is 0.298 atm? The density of kerosene is 0.800 g/cm3.
3. Adiabatic processes are those during which no heat is exchanged between the system and the surroundings. This term is often used as an approximation for processes that are very fast and have no heat exchange while the process is occurring, even if heat is eventually exchanged. Fans of Superman often attempt to describe the science of his superpowers. Use the idea of adiabatics to explain how Superman can freeze things with his breath.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to compare contrails and skywriting.

|  |  |  |
| --- | --- | --- |
|  | **Contrails** | **Skywriting** |
| **How produced (chemical equation)** |  |  |
| **Composition of vapor** |  |  |
| **Atmospheric conditions needed** |  |  |
| **Height of plane** |  |  |
| **Appearance** |  |  |

**Summary:** In the space below, or on the back of this paper, write a short email to a friend explaining the difference between contrails and skywriting.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **Classify each of the following as either chemical or physical processes. For each, explain your answer.**
   1. **Combustion**

*Chemical process. The bonds in the original compounds are broken and new bonds are formed.*

* 1. **Fractional Distillation**

*Physical process. This works on evaporation and condensation, both of which are physical processes. No bonds are broken or formed.*

1. **Examine the figure on page 13 and answer the following questions.**
   1. **What is distillation?**

*Boiling a liquid and then catching the vapor in a separate by cooling it down. This is a way of separating parts of a mixture by boiling point.*

* 1. **Why is the process in this figure called fractional distillation?**

*Crude oil is made of many different compounds. Each boiling range is specific to a fraction of the molecules in the mixture, so each range is separately condensed.*

* 1. **Why must crude oil go through this process in order to be useful?**

*Most uses for substances require specific molecules. Crude oil is a mixture of many different compounds that can be used in very different ways.*

* 1. **Describe the relationship between molecular mass, density, and boiling point for hydrocarbons.**

*A lower molecular mass has a lower density and a lower boiling point. All three are positively correlated.*

* 1. **Use molecule structure to explain the relationship between molecular mass and boiling point.**

*Smaller molecules have lower polarizability, so their London dispersion forces are not as attractive as larger molecules with higher polarizability, therefore smaller molecules have lower boiling points and larger molecules have higher boiling points.*

1. **If there are seven carbons in an alkane, then what is its molecular formula? Write the balanced chemical equation for the combustion of this seven-carbon compound.**

*C7H16*

*C7H16 + 11 O2 🡪 7 CO2 + 8 H2O*

1. **What is the molecular mass of kerosene?**

*170.34 amu (using molecular mass strictly) or 170.34 g/mol (using molar mass)*

1. **When we see a contrail in the sky, it is not the water vapor from the combustion reaction that we see. Explain what happens to allow us to see this contrail.**

*The water vapor from combustion spreads into the atmosphere and condenses into liquid, then freezes into solid around small particles in the atmosphere, where water vapor from the atmosphere also crystallizes. It is the frozen water around the particles that we see as the contrail.*

1. **Would you expect a contrail to last longer on a humid day or a dry day (assuming the same temperature)? Explain.**

*It should last longer on a humid day because there are more water molecules in the atmosphere to crystallize onto the particles, making them last longer before dissipating.*

1. **An aerosol is one subcategory of a colloid. Colloids have particles of one substance with a size between 1 and 1000 nm dispersed in another substance. Each part of this mixture can be of any phase and the phase combination is what classifies them into their subcategories. Use the table and the figure on page 14 to answer the questions below:**

**How many nanometers are in a micrometer?**

1000 micrometers = 1 nm

* 1. **How many nanometers are in a kilometer?**

1012 nanometers = 1 km

* 1. **How many nanometers are in a millimeter?**

*1,000,000 nm = 1 mm*

1. **Why don’t skywriters simply rely on contrails to do their writing, rather than adding in other substances?**

*They fly at 10,000 feet, rather than 30,000 feet, so the air isn’t cold enough to crystallize enough water to make it very visible.*

1. **Why do contrails and the smoke from skywriting dissipate fairly quickly, even on a day without any wind?**

*All molecules are in motion all the time. Over time, the air molecules and the molecules in the contrail or smoke will run into each other and eventually mix and spread.*

**Questions for Further Learning**

1. **Which would make more water when combusted in oxygen, 1 mole of C10H22 or 1 mole of C15H32? Explain, but do not use calculations.**

*C15H32 has more hydrogens that will turn into H2O during combustion, so it will make more water.*

1. **To what total volume will the water vapor from the combustion of 1.00 liter of kerosene spread when released in the atmosphere at 30,000 feet, where the temperature is -47.8oC and the pressure is 0.298 atm? The density of kerosene is 0.800 g/cm3.**
2. **Adiabatic processes are those during which no heat is exchanged between the system and the surroundings. This term is often used as an approximation for processes that are very fast and have no heat exchange while the process is occurring, even if heat is eventually exchanged. Fans of Superman often attempt to describe the science of his superpowers. Use the idea of adiabatics to explain how Superman can freeze things with his breath.**

*Student answers will vary.*

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# 

# Additional Resources

**Labs and demos**

Whoosh bottle: In this demonstration, you will show students how hydrocarbons combust and that the products are no longer combustible. Do not let students do this experiment, it must be done as a demo. <https://www.flinnsci.com/api/library/Download/bf2f0d16dd86411ea26eb0cb687dc593>

**Simulations and Videos**

Gas laws: <https://phet.colorado.edu/en/simulation/gas-properties>

Balancing chemical equations: <https://phet.colorado.edu/en/simulation/balancing-chemical-equations>

Video of phase diagram basics. <https://www.youtube.com/watch?v=ejg27ozbPA8>

**Lessons and lesson plans**

Simulation Activity: Balancing Chemical Equations: In this activity, students will learn how to count atoms and how to balance chemical equations using a simulation and games from PhET Interactive Simulations. <https://teachchemistry.org/classroom-resources/simulation-activity-balancing-chemical-equations>

What Type of Mixture is Paint: In this lesson students will use simple laboratory tests to characterize differences between solutions, colloids, and suspensions. They will then apply those tests to paints to classify them as specific types of mixtures. <https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>

**Projects and extension activities**

An extension of combustion could be done to compare the theoretical fuel efficiency of various hydrocarbons or alcohols, like in this AACT lesson: <https://teachchemistry.org/classroom-resources/evaluating-fuels>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Chemistry basics – Chemical and Physical changes; Physical properties
* Gases – Temperature
* Quantitative Chemistry – SI units
* Solutions – Mixtures
* States of Matter – Boiling point

**Correlations to Next Generation Science Standards**

This article relates to the following performance expectations and dimensions of the NGSS:

**HS-PS2-6**.

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

**HS-ETS1-3**

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

**Disciplinary Core Ideas**:

* PS1.A: Structure and Properties of Matter
* ETS1.C: Optimizing the design solution

**Crosscutting Concepts:**

* Cause and Effect: Mechanism and explanation
* Structure and Function

**Science and Engineering Practices:**

* Developing and using models
* Constructing explanations (for science) and designing solutions (for engineering)

**Nature of Science:**

* Scientific knowledge is based on empirical evidence.
* Scientific knowledge assumes an order and consistency in natural systems.

Student Reading Comprehension Questions – connections to NGSS Crosscutting Concepts:

* Q2: Patters + Systems & System Models
* Q7: Scale, Proportion, and Quantity + Systems & System Models

**Correlations to Common Core State Standards**

See how *ChemMatters* correlates to the[**Common Core State Standards**](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html)  at www.acs.org/chemmatters.

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* Alternative to the Anticipation Guide: Before reading, ask students if they have seen contrails, where they have seen them, and what they think they are made of. Also ask them if they have seen skywriting, and what questions they have about skywriting. As they read, students should record information they find interesting and look for answers to their questions.
* Show (or ask students to watch) the three-minute video clip referenced in the article to learn more about contrails.
* This lesson could be a phenomenon-based lesson, with skywriting or contrails being the phenomenon to investigate through combustion reactions.
* Ask students what they found most interesting from reading article.
* Using phase diagrams, pressure and temperature are easy to find at various altitudes. This can be used to interact with a phase diagram to learn all of its parts and to explain why the water condenses and then crystallizes in the upper atmosphere to make a contrail.