

**Teacher’s Guide**

 **What’s in Your Paintbox?**

***February 2023***

#

**Table of Contents**

[***Anticipation Guide***](#_Anticipation_Guide)***2***

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

[***Reading Comprehension Questions***](#_Student_Reading_Comprehension) ***3***

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***](#_Graphic_Organizer) ***6***

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***](#_Answers_to_Reading) ***7***

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

[***Additional Resources***](#_Additional_Resources_and) ***10***

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

***[Chemistry Concepts and Standards](#_Chemistry_Concepts_and) 12***



# Anticipation Guide

**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. “Pigment” is another word for “paint.” |
|  |  | 2. Ancient paint colors were made of organic compounds. |
|  |  | 3. Some of the first paints were made from compounds in soil or ashes from fires. |
|  |  | 4. Many paints containing heavy metals are prohibited today. |
|  |  | 5. Synthetic organic pigments tend to be brighter and more intense than inorganic pigments. |
|  |  | 6. Both acrylic and watercolor paints are colloidal suspensions. |
|  |  | 7. Many inorganic pigments are compounds containing transition metals. |
|  |  | 8. All colors except blue are absorbed by blue pigments. |
|  |  | 9. The length of the carbon chains in organic pigments determine the color perceived. |
|  |  | 10. Azo compounds have double bonds between nitrogen atoms. |

# Student ReadingComprehension Questions

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

1. One significant property of a pigment is that it is **insoluble** in its medium. Imagine two cups of water. Transfer some red drink mix powder (water soluble) into one and a red pigment (water insoluble) into the other. Describe how the drink mix mixture will look different from the red pigment mixture.
2. What is meant by the phrase “synthetic organic pigments”, and how are they different from naturally occurring pigments?
3. Consider a solution, like iced tea or your favorite sports drink.
	1. Explain how you can tell that paint should not be classified as a solution.
	2. In a colloid, particles of the “*dispersed medium*” are spread out among the “*continuous medium*” but are not dissolved. Using the two italicized terms, complete the following analogy to the parts of a solution:
		1. Solution: Colloid
		2. Solvent:
		3. Solute:
4. Explain the differences between a colloid, an emulsion, and a suspension.
5. Complete the chart:

|  |  |  |
| --- | --- | --- |
| **Paint Type** | **Liquid Medium** | **Binder** |
| Oil Paint |   |   |
| Acrylic Paint |   |   |
| Water Paint |   |   |

1. What is the purpose of each paint component:
	1. Liquid medium
	2. Binder
	3. Pigment
2. Consider the image on page 15 that shows light reflecting from a blue pigment, along with the explanations related to absorption of light. If red, green, and blue light all strike a blue pigment, why does only the blue get reflected? What happens to the red and green light in this scenario?
3. The energy of a visible light photon can be absorbed by a pigment if the photon’s energy has an appropriate magnitude to move an electron to a different location, or energy state, within the pigment.
	1. What structural aspect of transition metal atoms allows them to be used in pigments?
	2. What bonding feature should an organic molecule have if it is to be used for a pigment?
4. Substances that are based primarily on chains of carbon are classified as “organic” compounds. Those not based on carbon are classified as “inorganic” compounds.
	1. Write the chemical formula for the following compounds that are found in naturally occurring pigments:
		1. The molecule in red ochre
		2. The two main components of raw sienna
	2. Copy the structures of the organic compounds: alizarin, indigo, and the yellow azo dye. With a crayon or highlighter, identify, on each molecule, one example of where conjugation occurs.
		1. Why are these compounds classified as organic?
		2. Why is the yellow dye classified as an azo dye, while the other two are not?
5. The three dye molecules, as pictured on page 16, each absorb photons in different ranges, leading to their different colors. Rank the photons best absorbed by each of the three dyes in order from lowest to highest energy.
6. The alizarin dye can absorb photons with a wavelength of 274 nm.

a. Are these photons in the visible, infrared, or ultraviolet range?

b. What is the energy of a photon with this wavelength?

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

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

1. Create a summary chart of the physical and chemical properties of the various types of paints. Then give an example of applications for each paint type. For example, when would an acrylic paint be chosen over an oil paint?
2. Discuss the ways that polymerization occurs in different types of paints.

# Graphic Organizer

**Directions**: As you read, complete the graphic organizer below to describe the chemistry of paint and pigments.

|  |  |  |
| --- | --- | --- |
|  | **Inorganic Pigments** | **Organic Pigments** |
| **Ancient** |   |   |
| **Synthetic** |   |   |
| **How do we perceive their color?** |   |   |

|  |  |  |
| --- | --- | --- |
|  | **Components** | **Examples** |
| **Oil paint** |   |   |
| **Acrylic or latex paint** |   |   |
| **Watercolor paint** |  |   |

**Summary:** On the back of this sheet, write three interesting facts you learned from the article to share with a friend who enjoys painting.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. One significant property of a pigment is that it is **insoluble** in its medium. Imagine two cups of water. Transfer some red drink mix powder (water soluble) into one and a red pigment (water insoluble) into the other. Describe how the drink mix mixture will look different from the red pigment mixture.

The drink mix would look red and transparent. You’d be able to see through it, and it would look like a single red liquid.

The pigment mix would look like dirty water. You would see the solid floating around (and eventually settling) and you would not be able to see through the mixture.

1. What is meant by the phrase “synthetic organic pigments”, and how are they different from naturally occurring pigments?

Pigments that are made in the lab, rather than gathered from the earth or from an organism. Some synthetic pigments use naturally occurring pigments within the synthesis, but chemically change them to suit the needs of the experimenter. Naturally occurring pigments are colored compounds that exist naturally in an organism or in the earth.

1. Consider a solution, like iced tea or your favorite sports drink.
	1. Explain how you can tell that paint should not be classified as a solution.

You cannot see through paint. Solutions look like a single liquid, and have the particles of the solute completely surrounded by particles of the solvent.

* 1. In a colloid, particles of the “*dispersed medium*” are spread out among the “*continuous medium*”, but are not dissolved. Using the two italicized terms, complete the following analogy to the parts of a solution:
		1. Solution: Colloid
		2. Solvent: continuous medium
		3. Solute: dispersed medium
1. Explain the differences between a colloid, an emulsion, and a suspension.

A suspension has large particles dispersed throughout another substance. The particles will eventually settle out of the mixture, due to gravity.

A colloid has smaller particles (but not as small as a solution) dispersed throughout another substance. The particles will stay dispersed in the mixture, just like they would in a solution.

An emulsion is a type of colloid where both the dispersed and the continuous media are in the liquid state, and the particles cannot mix with each other, like in a solution. An emulsion will separate into its individual liquids unless an emulsifying agent is added that can keep the two liquids mixed by interacting with each of the particle types.

1. Complete the chart:

|  |  |  |
| --- | --- | --- |
| **Paint Type** | **Liquid Medium** | **Binder** |
| Oil Paint |  Linseed oil |  Linseed oil |
| Acrylic Paint |  Water |  Methyl Acrylate |
| Water Paint |  Water | Gum Arabic |

1. What is the purpose of each paint component:
	1. Liquid medium – Allows the binder/pigment to be spread onto a surface
	2. Binder – Traps or bonds the pigment so it sticks to the painted surface
	3. Pigment – Gives the color
2. Consider the image on page 15 that shows light reflecting from a blue pigment, along with the explanations related to absorption of light. If red, green, and blue light all strike a blue pigment, why does only the blue get reflected? What happens to the red and green light in this scenario?
The red and green light are absorbed into the pigment, so only the blue reflects away and is seen by the observer.
3. The energy of a visible light photon can be absorbed by a pigment if the photon’s energy has an appropriate magnitude to move an electron to a different location, or energy state, within the pigment.
	1. What structural aspect of transition metal atoms allows them to be used in pigments?
	The d-orbitals are in an energy state that allows electrons to move to new levels when absorbing light in the visible range of the electromagnetic spectrum.
	2. What bonding feature should an organic molecule have if it is to be used for a pigment?
	The molecule needs conjugation (alternating single and double bonds).
4. Substances that are based primarily on chains of carbon are classified as “organic” compounds. Those not based on carbon are classified as “inorganic” compounds.
	1. Write the chemical formula for the following compounds that are found in naturally occurring pigments:
		1. The molecule in red ochre – Fe2O3
		2. The two main components of raw sienna – FeO (or Fe2O3) and MgO
	2. Copy the structures of the organic compounds: alizarin, indigo, and the yellow azo dye. With a crayon or highlighter, identify, on each molecule, one example of where conjugation occurs.
	All three structures should be drawn and at least one adjacent single bond and double bond should be highlighted.
		1. Why are these compounds classified as organic?
		Because they are primarily chains of carbons.
		2. Why is the yellow dye classified as an azo dye, while the other two are not?
		Because it has a nitrogen – nitrogen double bond (N=N) and the others do not.
5. The three dye molecules, as pictured on page 16, each absorb photons in different ranges, leading to their different colors. Rank the photons best absorbed by each of the three dyes in order from lowest to highest energy.
Red (alizarin) < Yellow (azo dye) < Blue (indigo)
6. The alizarin dye can absorb photons with a wavelength of 274 nm.

a. Are these photons in the visible, infrared, or ultraviolet range?

 Ultraviolet

b. What is the energy of a photon with this wavelength?

$$E=\frac{hc}{λ}=\frac{(6.626 × 10^{-34}J⋅s)(2.998 × \frac{10^{8}m}{s})}{2.74 × 10^{-7}m}= 7.25×10^{-19}J$$

**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 |

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# Additional Resources and Teaching Strategies

**Additional Resources**

* **Labs and demos**
* 5E Laboratory Lesson: What Type of Mixture is Paint?<https://teachchemistry.org/classroom-resources/what-type-of-mixture-is-paint>
* 5E Laboratory Lesson: Exploring the Chemistry of Oil and Acrylic Paints <https://teachchemistry.org/classroom-resources/exploring-the-chemistry-of-oil-and-acrylic-paints>
* 5E Laboratory Lesson: Transition Metals Color the World <https://teachchemistry.org/classroom-resources/transition-metals-color-the-world>
* **Simulations**
* Chemistry of Color Video Series:<https://teachchemistry.org/classroom-resources/collections/chemistry-of-color?utf8=%E2%9C%93&q%5Bresource_topics_topic_id_or_resource_topics_topic_parent_topic_id_in%5D%5B%5D=&q%5Bcontent_type_in%5D%5B%5D=video&q%5Bcontent_type_in%5D%5B%5D=&button=>
* ACS Podcast: How Eggplants Inspired Sustainable Paint <https://www.acs.org/catalyzing-change/how-eggplants-inspired-sustainable-paint.html>
* Animation: The Electromagnetic Spectrum <https://teachchemistry.org/classroom-resources/the-electromagnetic-spectrum-animation>
* **Lessons and lesson plans**
* AACT Resource Collection “The Chemistry of Color” <https://teachchemistry.org/periodical/issues/september-2017/introducing-the-chemistry-of-color-a-resource-collection>
* What is Paint? A Paint Investigation <https://teachchemistry.org/classroom-resources/what-is-paint-a-paint-investigation>
* Isolation of Phytochrome <https://teachchemistry.org/classroom-resources/isolation-of-phytochrome>
* **Projects and extension activities**
	+ Fields of Specialization: Dyes, Paints, Pigments, Coatings<https://www.acs.org/careers/chemical-sciences/fields/dyes-paints-pigments-coatings-inks.html>

**Teaching Strategies**

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

* **Alternative to Anticipation Guide:** Before reading, ask students if they enjoy painting and/or visiting art galleries and what types of paints they use or have heard about. Their initial ideas can be collected electronically via Jamboard, Padlet, or similar technology.
	+ As they read, students can find information to confirm or refute their original ideas.
	+ After they read, ask students what they learned about how chemistry can help artists create paintings for us to appreciate.
* After students have read and discussed the article, ask students what they would like to share with friends and family about paints.
* This article could be used when discussing basic types of matter and could be used with some of the above lessons to explore different types of mixtures.
* This article could be used when introducing light and the electromagnetic spectrum, and could be contrasted with the electron processes that occur in flame tests.
* This article could be used when addressing bonding to highlight differences between molecular and ionic compounds, along with polymer formation.
* AACT Webinar: “STEAM: Using Paint to Teach Stoichiometry and Solutions” <https://teachchemistry.org/professional-development/webinars/steam-using-paint-to-teach-stoichiometry-and-solutions>

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Physical properties
* Chemical change
* Solutions
* Solute/solvent
* Electrons

**Correlations to Next Generation Science Standards**

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

**HS-PS1-3.** Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

**HS-ETS1-2.** Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* PS.3.A: Definitions of Energy
* ETS1.B: Developing Possible Solutions

**Crosscutting Concepts:**

* Cause and effect
* Structure and function
* Energy and matter

**Science and Engineering Practices:**

* Constructing explanations (for science) and designing solutions (for engineering)

**Nature of Science:**

* Science models, laws, mechanisms, and theories explain natural phenomena.

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