

**Teacher’s Guide**

**Keeping the Playing Field Level**

***December 2023***

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

[***Reading Comprehension Questions***](#_3znysh7) ***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***](#_fbh2674qb7v5) ***5***

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***](#_djipzn7z1r1b) ***6***

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

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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

**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. Athletes have used performance enhancing drugs (PEDs) only since the 1950s. |
|  |  | 2. The International Olympic Committee (IOC) has required drug testing at all Olympic events since 1960. |
|  |  | 3. The National Basketball Association (NBA) required drug testing prior to the National Football League (NFL) and Major League Baseball (MLB). |
|  |  | 4.Five categories of drugs are responsible for most doping violations by athletes. |
|  |  | 5. Blood and urine tests are used to look for banned drugs and their metabolites. |
|  |  | 6. Mass spectrometry and chromatography are used to identify substances in blood or urine. |
|  |  | 7. The first known synthetic testosterone was made in 1995. |
|  |  | 8. The ratios of carbon isotopes in hormones naturally produced by the body are compared to determine if one of the hormones is synthetic. |
|  |  | 9. Steroids account for only about 10% of all positive doping tests in sports. |
|  |  | 10. Steroid users have a higher mortality rate than non steroid users. |

# Student Reading Comprehension Questions

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

1. The World Anti-Doping Agency (WADA) developed a wide-ranging set of regulations when it was founded in 1999. What are the five major categories of prohibited substances and methods regulated by WADA?
2. Which of these five major categories accounts for over 50% of positive doping tests in sports?
3. If an athlete participated in archery, which type of performance-enhancing drug might they use? Explain.
4. Explain how the liver helps increase the solubility of the steroid stanozolol.
5. What is the purpose of the magnets in the mass spectrometer?
6. What are isotopes?
7. Use the mass spectrum graph to determine the percent abundance of carbon-12 and carbon-13.
8. Explain how the ratio of different carbon isotopes can be used to differentiate between a non-performance enhancing steroid that is produced in the body from a synthetic steroid used to enhance athletic performance.
9. How is the carbon-13 to carbon-12 ratio measured by the mass spectrometer?
10. What could cause a false positive test for synthetic steroids?

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

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

1. Research the dangers of long-term use of steroids. Identify at least two hazardous side effects.
2. Draw a diagram that shows how anabolic steroids accelerate muscle growth on the cellular level.

# Graphic Organizer

**Directions**: As you read, complete the graphic organizers below. In the first organizer, choose any four banned substances described in the article. In the second organizer, describe how IRMS works.

|  |  |  |  |
| --- | --- | --- | --- |
| **Drug** | **Drug type** | **Formula** | **Why is it used?** |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |
|  |  |  |  |

|  |  |  |
| --- | --- | --- |
|  | **Determines** | **How the analysis helps identify doping** |
| **Isotope Ratio** |  |  |
| **Mass** |  |  |
| **Spectrometry** |  |  |
| **Chromatography** |  |  |

**Summary:** On the back of this sheet, write three interesting facts you learned about how PEDs are detected.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. The World Anti-Doping Agency (WADA) developed a wide-ranging set of regulations when it was founded in 1999. What are the five major categories of prohibited substances and methods regulated by WADA?  
   Anabolic steroids, peptide hormones, stimulants, beta blockers, diuretics
2. Which of  these five major categories accounts for over 50% of positive doping tests in sports?  
   Steroids
3. If an athlete participated in archery, which type of performance-enhancing drug might they use? Explain.  
   Archery requires very steady hands in order to aim properly. Because beta blockers lower heart rate and blood pressure, this class of drugs would help an archer perform better.
4. Explain how the liver helps increase the solubility of the steroid stanozolol.  
   Cytochrome P450 in the liver metabolizes the stanozolol-a synthetic form of a steroid that mimics testosterone-to 3’-hydroxystanozolol by adding an -OH group to the molecule. The presence of this group allows for increased hydrogen bonding between water and 3’-hydroxystanozolol, leading to increased solubility.
5. What is the purpose of the magnets in the mass spectrometer?  
   Magnets bend the path of the molecular ions based on their mass, such that one type of ion hits the detector at a time.
6. What are isotopes?  
   Isotopes are different forms of the same element with different numbers of neutrons, so they have different masses. Carbon has four isotopes.
7. Use the mass spectrum graph to determine the percent abundance of carbon-12 and carbon-13.  
   Carbon-12 is overwhelmingly more abundant ~ 99% and carbon-13 is ~ 1%.
8. Explain how the ratio of different carbon isotopes can be used to differentiate between a non-performance enhancing steroid that is produced in the body from a synthetic steroid used to enhance athletic performance.  
   The ratio of carbon-13 to carbon-12 isotopes is 1:99 in carbon-containing compounds like steroids produced in the body. However, synthetic steroids have a different carbon-13 to carbon-12 ratio, because these compounds are made from plants. This difference can be detected by isotope ratio mass spectroscopy.
9. How is the carbon-13 to carbon-12 ratio measured by the mass spectrometer?  
   The compound in question is burned in the presence of oxygen to produce water vapor and carbon dioxide gas. The molecular mass of a molecule of carbon dioxide containing carbon-12 is 44 amu, but the molecular mass of a molecule of carbon dioxide containing carbon-13 is slightly heavier, 45 amu. The mass spectrum will show the abundance of the two forms of carbon dioxide, by the height of their peaks, and the ratio of their respective carbon isotopes can be calculated from these peak heights.
10. What could cause a false positive test for synthetic steroids?  
    A diet high in plant foods would mimic the carbon-13 to carbon-12 ratio often found in synthetic steroids, leading to a false positive test.
11. Research the dangers of long-term use of steroids. Identify at least two hazardous side effects.  
    Answers will vary depending on student research. Some examples include increased chance of cancer, liver disease and heart problems.
12. Draw a diagram that shows how anabolic steroids accelerate muscle growth on the cellular level.  
    The diagram should show that anabolic steroids attach to androgen receptors within the cells. This causes changes in receptor proteins that can then move from the cytoplasm of the cells to the nucleus and attach to the cell’s DNA. This changes the expression of the genes that make certain proteins, resulting in muscle growth.

**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 demonstrations**
  + Students investigate solubility and polarity of various solutions.  
    <https://teachchemistry.org/classroom-resources/solubility-and-compound-type>
* **Simulations**
  + Students inspect isotopes of many chemical elements.

<https://phet.colorado.edu/en/simulations/isotopes-and-atomic-mass>

* + Students explore a simulation of how a mass spectrometer works.

[https://applets.kcvs.ca/MassSpectrometer/massSpec.html#](https://applets.kcvs.ca/MassSpectrometer/massSpec.html)

* **Lessons and lesson plans**
  + Students read and research about the development of medicinal steroids and their structure in this multi-part lesson and activity.  
    <https://teachchemistry.org/classroom-resources/steroid-medicines-a-profile-of-chemical-innovation>
  + Students learn more about doping in sports.  
    <https://www.compoundchem.com/2016/08/09/doping/>

**Teaching Strategies**

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

* **Alternative to Anticipation Guide:** Before reading, ask students what performance enhancing drugs (PEDs) they have heard of, and how the tests for them are done. Ask if they know of any sports figures who have been penalized because of PEDs, and why. 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 the chemistry of performance enhancing drugs and the tests that are done to find them.
* After students have read and discussed the article, ask students what information they would like to share with friends and family about PEDs and how their ideas about PED testing have changed after reading the article.
* Consider showing the ACS Reactions Video: “How to catch Dopers” (3:45) <https://youtu.be/oWOwLwMc0rc?si=3w02K3hLuActj6LG>. The video focuses on anabolic-androgenic steroids and augments some of the information in the article.

# Chemistry Concepts and Standards

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Molecular structure
* Pharmaceuticals
* Instrumentation

**Correlations to Next Generation Science Standards**

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

**HS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

**Disciplinary Core Ideas:**

* PS.1.A: Structure and Properties of Matter
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Scale, proportion, and quantity
* Structure and Function

**Science and Engineering Practices:**

* Analyzing and interpreting data

**Nature of Science:**

* Scientific knowledge is based on empirical evidence.

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).