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

**Reading Comprehension Questions**  
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**  
This helps 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**  
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

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

**Chemistry Concepts, Standards, and Teaching Strategies**

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**Chemistry Concepts, Standards, and Teaching Strategies**

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Anticipation Guide

Directions: **Before reading the article**, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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.

<table>
<thead>
<tr>
<th>Me</th>
<th>Text</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1.</td>
<td>As of publication date, more than 30 fatalities were linked to vaping in 2019.</td>
</tr>
<tr>
<td></td>
<td>2.</td>
<td>As of publication date, flavored e-cigarettes are illegal in all states.</td>
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<tr>
<td></td>
<td>3.</td>
<td>Smoking traditional cigarettes is the leading preventable cause of death in the United States.</td>
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<tr>
<td></td>
<td>5.</td>
<td>E-cigarettes produce aerosols (tiny droplets) that the user inhales.</td>
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<td></td>
<td>6.</td>
<td>Alkaloids such as nicotine, caffeine, and fentanyl contain nitrogen.</td>
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<tr>
<td></td>
<td>7.</td>
<td>The conjugate base form of nicotine is readily absorbed by the lungs.</td>
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<tr>
<td></td>
<td>8.</td>
<td>Adding ammonium salts helps turn nicotine molecules into the conjugate base form.</td>
</tr>
<tr>
<td></td>
<td>9.</td>
<td>Flavor compounds in e-cigarettes may break down into formaldehyde.</td>
</tr>
<tr>
<td></td>
<td>10.</td>
<td>Nicotine is especially dangerous for teens because it induces a dopamine surge.</td>
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</tbody>
</table>
Student Reading Comprehension Questions

Directions: Use the article to answer the questions below.

1. Can you find all of the carbons in the THC structure on page 6? Verify that you found them all by comparing to the molecular formula.

2. How many bonds (indicate type) and how many lone pairs are on each nitrogen atom in the nicotine molecule?

3. Draw the complete Lewis structure for NH₃ and NH₄⁺.

4. When vaping, the user inhales an aerosol, rather than a vapor. What makes something an aerosol?

5. Classify each of the following as gas, vapor, or aerosol
   a. Clouds in the sky
   b. The gasoline smell from a gas station
   c. Oxygen breathed in from the air
   d. Cigarette smoke
   e. Moisture in the atmosphere
   f. Helium inside a balloon

6. How many grams of formaldehyde would be inhaled during the consumption of Gummy Bear flavored liquid in a 30 mL bottle, if its density is 1.25 g/mL?

7. Why is THC not in the same class of compounds as nicotine?

8. Biochemistry is the study of the chemical structures and processes that occur in living organisms. Small changes in the structures of molecules, like enzymes, can cause changes in how they function in an organism, which can disrupt the system. What structural change do tobacco companies utilize to increase the percentage of nicotine that the lungs will absorb from their cigarettes?
9. Look at the two chemical equations in the “One Proton Difference” box. Assume the second reaction is in equilibrium. Justify, using equilibrium principles, why adding ammonia salts will favor the conjugate base form of nicotine.

10. The Juul product is made to have a smooth feel, leading the user to think the nicotine level is low and making it popular among teens. However, it was found that the Juul liquids contained more than five times the nicotine as other similar brands. The Juul liquid contained a lower percentage of the harsher, but better-absorbing, base form of nicotine, but a higher amount of total nicotine. Propose a scientific experiment (assuming non-human test subjects) that could be done to determine how much more nicotine is absorbed when in base form as opposed to acid form.

11. A friend of yours is considering taking up vaping and says that it is totally safe, because she plans on getting the nicotine-free kind. Refute your friend’s claim using evidence from the article and reasoning to support it.

Questions for Further Learning

Write your answers on another piece of paper if needed.

1. Formaldehyde is a chemical typically used in embalming fluid. Research the effects formaldehyde has on a human body that makes it good for embalming.

2. One suggestion for helping reduce teen vaping is to pass a law that vaping liquids cannot have a pH less than 9. Explain why this proposal would likely help to reduce the numbers of teens who vape.

3. Watch a short video: https://www.youtube-nocookie.com/embed/ELKUlJEAiHI
   Explain why vaping THC is even more dangerous than smoking it.
Vaping: What You Need to Know, December 2019

**Graphic Organizer**

**Directions**: As you read, complete the graphic organizer below to compare e-cigarettes and traditional cigarettes.

<table>
<thead>
<tr>
<th></th>
<th>E-cigarettes</th>
<th>Traditional Cigarettes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemicals in the cigarettes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chemicals produced during use of the cigarettes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Effects on the brain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Flavors</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Summary**: On the back of this sheet, write a short letter to a friend who vapes describing what you learned about the harm e-cigarettes could be causing him/her.
Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. Can you find all of the carbons in the THC structure on page 6? Verify that you found them all by comparing to the molecular formula.
   *In a line diagram, every angle or intersection represents a carbon (as long as there is not already another element there).*

2. How many bonds (indicate type) and how many lone pairs are on each nitrogen atom in the nicotine molecule?
   *The N on the 6-membered ring has one single and one double bond and one lone pair. The N on the 5-membered ring has three single bonds and one lone pair.*

3. Draw the complete Lewis Structure for NH$_3$ and for NH$_4^+$.

   ![](image)

4. When vaping, the user inhales an aerosol, rather than a vapor. What makes something an aerosol?
   *An aerosol contains submicroscopic particles (if solid) or droplets (if liquid) suspended in air or another gas.*

5. Classify each of the following as gas, vapor, or aerosol
   a. Clouds in the sky  aerosol
   b. The gasoline smell from a gas station  vapor
   c. Oxygen breathed in from the air  gas
   d. Cigarette smoke  aerosol
   e. Moisture in the atmosphere  vapor
   f. Helium inside a balloon  gas

6. How many grams of formaldehyde would be inhaled during the consumption of the Gummy Bear flavored liquid in a 30.0 mL bottle with a density of 1.25 g/mL?
   
   \[
   \text{mass of formaldehyde} = \text{volume of liquid} \times \text{density of liquid} \times \frac{1 \text{g}}{1 \times 10^6 \mu\text{g}} = 0.206 \text{ g formaldehyde}
   \]

7. Why is THC not in the same class of compounds as nicotine?
   *It does not contain a nitrogen atom.*
8. Biochemistry is the study of the chemical structures and processes that occur in living organisms. Small changes in the structures of molecules, like enzymes, can cause changes in how they function in an organism, which can disrupt the system. What structural change do tobacco companies utilize to increase the percentage of nicotine that the lungs will absorb from their cigarettes? They convert the nicotine to its base form, which is different from its acid form. The base form has been shown to absorb better into the lungs, so this change increases the amount of nicotine a user gets from the tobacco, which increases the chance of addiction.

9. Look at the two chemical equations in the “One Proton Difference” box. Assume the second reaction is in equilibrium. Justify, using equilibrium principles, why adding ammonia salts will favor the base form of nicotine.

When the ammonium salt is heated, ammonia gas forms. This ammonia will remove the acidic hydrogen on the acid form of nicotine, turning it to the base form. According to LeChâtelier’s Principle, adding more ammonia will shift the reaction toward the base form of the molecule.

10. The Juul product is made to have a smooth feel, leading the user to think the nicotine level is low and making it popular among teens. However, it was found that the Juul liquids contained more than five times the nicotine as other similar brands. The Juul liquid contained a lower percentage of the harsher, but better-absorbing, base form of nicotine, but a higher amount of total nicotine. Propose a scientific experiment (assuming non-human test subjects) that could be done to determine how much more nicotine is absorbed when in base form as opposed to acid form.

The experiment should include an independent variable (something like the amount or ratio of acid and base forms); a dependent variable (something related to the absorption in the lungs); controlled variables (all other conditions: type of heating element, dispenser, length of puff, etc.) and a plan to collect data.

11. A friend of yours is considering taking up vaping and says that it is totally safe, because she plans on getting the nicotine-free kind. Refute your friend’s claim using evidence from the article and reasoning to support it.

The discussion should contain evidence from the article, specifically that the flavors have been found to turn into many dangerous/toxic chemicals when heated.

Questions for Further Learning

1. Formaldehyde is a chemical typically used in embalming fluid. Research the effects formaldehyde has on a human body that makes it good for embalming. It works by irreversibly connecting cell proteins to other proteins or to DNA through covalent bonds. This stops the cells from being able to function and provides a firmness to the deceased person’s skin, so their body looks more normal for several days.

2. One suggestion for helping to reduce teen vaping is to pass a law that vaping liquids cannot have a pH less than 9. Explain why this proposal would likely help to reduce the numbers of teens who vape. At a pH of 9, the base form of nicotine would be prevalent in the solution. Since this has a much harsher feel when inhaled, it is likely that younger people would be less inclined to use it.

3. Watch the short video at the following link: https://www.youtube-nocookie.com/embed/ELKUljEalHI Explain why vaping THC is even more dangerous than smoking it. It makes the user inhale a much more concentrated and pure form of the THC, which can be more dangerous.
**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.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
<th>Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Excellent</td>
<td>Complete; details provided; demonstrates deep understanding.</td>
</tr>
<tr>
<td>3</td>
<td>Good</td>
<td>Complete; few details provided; demonstrates some understanding.</td>
</tr>
<tr>
<td>2</td>
<td>Fair</td>
<td>Incomplete; few details provided; some misconceptions evident.</td>
</tr>
<tr>
<td>1</td>
<td>Poor</td>
<td>Very incomplete; no details provided; many misconceptions evident.</td>
</tr>
<tr>
<td>0</td>
<td>Not acceptable</td>
<td>So incomplete that no judgment can be made about student understanding</td>
</tr>
</tbody>
</table>
Additional Resources

Labs and demos
A demo of something that decomposes easily with heat would be useful to show students that the things that go into the e-cigarette are not the same as the thing that comes out. Try out this demo from AACT: Sterno – In this demo, students will observe a decomposition reaction that triggers a precipitate reaction that prevents a solution from conducting electricity. https://teachchemistry.org/classroom-resources/sterno

Simulations

Projects and extension activities
This website: https://teens.drugabuse.gov/ has a lot of good resources for both teens and teachers!
This C&EN article has additional background information on this subject – Hunting for the cause of mystery vaping illnesses: https://cen.acs.org/biological-chemistry/toxicology/Hunting-cause-mystery-vaping-illnesses/97/web/2019/10
This FDA site has some infographics to discourage teen vaping: https://digitalmedia.hhs.gov/tobacco/print_materials/search?tag=E-cigarettes%2Fvaping
Connections to Chemistry Concepts
The following chemistry concepts are highlighted in this article:

- Acids and Bases
  - Acid-base reactions
- Organic Chemistry
  - Functional groups
  - Pharmaceuticals
- States of Matter

Correlations to Next Generation Science Standards
This article can be used to achieve the following performance expectations of NGSS:

**HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

**Disciplinary Core Ideas:**

**Crosscutting Concepts:**
- Cause and Effect: Mechanism and explanation.
- Scale, Proportion, and Quantity
- Structure and Function

**Science and Engineering Practices:**
- Asking questions (for science) and defining problems (for engineering)

**Nature of Science:**
- Scientific knowledge is based on empirical evidence.
- Science addresses questions about the natural and material world

See how ChemMatters correlates to the Common Core State Standards online at www.acs.org/chemmatters.

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

- **Alternative to Anticipation Guide:** Before reading, ask students what they know about vaping, and possible dangers of vaping. As they read, students can find information to confirm or refute their original ideas.
- Ask students to find other consumer products containing glycerin and propylene glycol, two compounds found in the liquid for e-cigarettes, and compare their health effects.
- This article could be used during a unit on structure and bonding, as a phenomenon around which to base the lesson. (NGSS Connection: HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.)
- This could also be used to design a unit involving equilibrium (and possibly kinetics). The focus could be on why some liquids are much more harsh than others and why this is essentially tricking young people into using them. (NGSS Connection: HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.)