## Common Products of Combustion

<table>
<thead>
<tr>
<th>Course</th>
<th>Rationale</th>
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<tr>
<td>Firefighter I</td>
<td>In order to stay alive, firefighters must understand the dangers of fire’s heat and flame. The products of combustion, such as fire gases and smoke, are often the cause of death at a fire scene. Firefighters must consciously and constantly be aware of the hazards caused by all of the products of combustion.</td>
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<th>Unit II</th>
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<td>Safety and Orientation</td>
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<tr>
<th>Essential Question</th>
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<td>Why should firefighters understand the hazards that fire gases pose to human life?</td>
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<td>(10)(A)</td>
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<th>Prior Student Learning</th>
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<th>Estimated Time</th>
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<th>Objectives</th>
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<td>The students will be able to:</td>
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<tr>
<td>1. Define combustion and describe the four basic products of combustion (heat, flame, smoke, and fire gases)</td>
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<td>2. Explain the hazards that each basic product of combustion poses to life</td>
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<td>3. Describe and explain the three most common fire gases found during combustion (carbon monoxide (CO), hydrogen cyanide (HCN), and carbon dioxide (CO₂))</td>
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<td>4. Describe and explain the effects on humans of CO, HCN, and CO₂, including their narcotic asphyxiation properties</td>
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<td>5. Identify the irritants that are common in smoke</td>
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<td>6. Explore the other common products (gases) of combustion and their toxic effects</td>
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<td>7. Understand the basic process of respiration in humans in order to explain how fire gases affect humans</td>
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<th>Engage</th>
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<td>Have the students watch a video about CO poisoning. (Note: To find a video do an Internet search for the following key words: firefighter recovering from Carbon Monoxide video.) Use this to inspire a class discussion about the dangers of the products of combustion (seen and unseen). Use the Discussion Rubric for assessment.</td>
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<th>Key Points</th>
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<td>I. Combustion.</td>
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<td>A. Combustion – a rapid and self-sustaining chemical process that yields heat, light, usually in the form of flame, and other products including smoke and fire gases (i.e. fire) (IFTSA, 2008)</td>
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<td>B. Modes of combustion</td>
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<td>1. Are differentiated based on where the reaction is occurring</td>
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<td>a) Flaming combustion</td>
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<td>(1) Is oxidation that involves fuel in the gas phase</td>
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<td>(2) Requires liquid or solid fuels to be vaporized</td>
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<td>b) Non-flaming or smoldering combustion</td>
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<td>(1) Is oxidation that occurs on the surface of some solid fuels, particularly those that are porous and can char</td>
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(a) Charcoal
(b) Some types of fabric and upholstery

C. Four common products of combustion

1. Heat/heat energy
   a) Is a danger to anyone directly exposed to it
      (1) Burns
      (2) Damage to the respiratory tract
      (3) Dehydration
      (4) Heat exhaustion

2. Flame (light)
   a) Is the luminosity created by the flame
   b) Does not pose a hazard
      (1) Note: The flame is the fire itself. It burns and spreads the fire by direct contact and through the heat that is produced by the combustion of the fuel (See: transfer of heat)

3. Smoke
   a) Is an aerosol composed of gases, vapor, and solid particulates
   b) Is toxic to human life – poses a respiratory hazard caused by its irritants
   c) Contains a wide range of irritants that depend upon the type of fuel
      (1) Irritants in smoke are the substances that cause
         (a) Breathing discomfort
         (b) Inflammation of the eyes, respiratory tract, and skin
      (2) Fire gases that are toxic to human life are found in smoke
      (3) The toxic effects of smoke inhalation result from the interrelated effect of all the toxic products present

4. Fire Gases
   a) Contain toxic gases and flammable gases
   b) Are generally colorless
   c) Common (toxic) fire gases
      (1) Carbon Monoxide (CO)
         (a) Is a byproduct of the incomplete combustion of organic materials
         (b) Is probably the most commonly encountered product of combustion in structure fires
         (c) Is identified as the cause of death for civilians and firefighters without respiratory protection
         (d) Is an asphyxiant
      (2) Hydrogen cyanide (HCN)
         (a) Is produced in the combustion of materials containing nitrogen, also found in smoke
         (b) Acts as a chemical asphyxiant, preventing the body
from using oxygen at the cellular level

(3) Carbon dioxide (CO₂)
   (a) Is a product of the complete combustion of organic materials
   (b) Acts as a simple asphyxiant by displacing oxygen
   (c) Acts as a respiratory stimulant that increase the respiratory rate

(4) Combustion produces many other common toxic gases, the specific compositions of which
   (a) Vary from fuel to fuel
   (b) Have various toxic effects

   d) Flammable gases
   (1) Present during some structural fires
   (2) Result from the incomplete combustion of some fuels
   (3) Are dangerous when mixed with the right concentration of oxygen because they can
      (a) Increase the fire load
      (b) Make the fire burn more completely
         (i) When this happens the luminosity of the flame is lost
         (ii) The lack of luminosity makes the flame difficult to see, which puts firefighters at a greater risk of injury or death

II. Introduction to Human Respiration
A. Basic Anatomy
   1. Nose
   2. Mouth
   3. Pharynx (throat)
   4. Larynx (voice box)
   5. Trachea (windpipe)
   6. Bronchi (two branches off of the trachea that go into each lung)
   7. Lungs
      a) Anatomy within the lungs
         (1) Bronchioles – air passages that connect the bronchi and the alveoli
         (2) Alveoli – small air-containing compartments located at the end of the bronchioles where respiratory gases are exchanged with the pulmonary capillaries
         (3) Pulmonary capillaries – the small blood vessels that surround the alveoli
      b) Primary function is gas exchange
         (1) Inhalation of oxygen for cellular respiration
         (2) Exhalation of waste products, primarily carbon dioxide

B. The Gas Exchange
   1. Is a process of diffusion that occurs where the alveoli membrane
meets the pulmonary capillaries
2. Diffuses oxygen into the blood stream and the high concentration of CO₂ from the deoxygenated blood
C. Affinity of Hemoglobin to CO
1. Hemoglobin – the part of blood that contains iron, carries oxygen through the body, and gives blood its red color
2. Oxyhemoglobin (O₂Hb) – when blood’s hemoglobin combines with and carries oxygen in a loose chemical combination
3. Carboxyhemoglobin (COHb) – when CO combines with the blood’s hemoglobin
4. The affinity between CO and hemoglobin is 200 times stronger than the affinity between oxygen and hemoglobin
D. Respiratory Protection – the protective measures against respiratory hazards such as smoke, toxic atmospheres, and oxygen deficiency
1. Toxic – being or containing poisonous material capable of causing death or serious debilitation
2. Hypoxia – a condition caused by oxygen deficiency

Activities
1. **Common Products of Combustion Stations** – Set up four stations in your classroom (heat/heat energy, flame, smoke, and fire gases). Each station should have markers and poster boards. Divide the class into four groups. Have one group at each station. Give each group five minutes to write or draw what its members know about that product of combustion. When five minutes has passed, have the groups rotate to the next station. Repeat this until each group has visited all of the stations. Then discuss the students’ work as a class. Use the Discussion Rubric for assessment.

2. **Carbon Monoxide (CO) Poisoning Public Service Announcement (PSA)** – Have students research CO poisoning and then create a PSA. The PSA should warn young people of the dangers of CO poisoning. Students may work in groups or as individuals. Each PSA should be created using the students’ media of choice (i.e. presentation software, video, radio, etc.). If technology is unavailable, the students can perform the PSA in front of the class acting as a live, studio audience. Use the Presentation Rubric and the Group Evaluation Rubric, or the Individual Work Rubric for assessment.

Assessments
Common Products of Combustion Quiz and Key
Discussion Rubric
Group Evaluation Rubric
Individual Work Rubric
Presentation Rubric
Writing Rubric

Materials
Common Products of Combustion computer-based presentation
Posters and drawing materials (enough for four groups)
Computers with Internet access
Audio or visual equipment, optional

Resources
0135151112, Essentials of Firefighting (5th Edition), International Fire Service Training Association (IFSTA)
http://www.lung.org/your-lungs/how-lungs-work/?gclid=CNPersHn2LwCFdFAMgodzT0ADA

Do an Internet search for the following key words: respiratory system video education with vision

Accommodations for Learning Differences
For reinforcement, students will watch a brief video about the respiratory system and then draw a diagram or write a description of the process.
(Notes: To find a video conduct an Internet search for the following key words: respiratory system video education with vision. Another helpful resource is the interactive diagram found at http://www.lung.org/your-lungs/how-lungs-work/?gclid=CNPersHn2LwCFdFAMgodzT0ADA.) Use the Individual Work Rubric for assessment.

For enrichment, students will write a short research paper about the toxic effects of some of the common products of combustion that were not discussed in this lesson. Some examples include: actetaldehyde, acrolein, asbestos, benzene, benzaldehyde, formaldehyde, glutaraldehyde, hydrogen chloride, isovaleraldehyde, nitrogen dioxide, particulates, polycyclic aromatic hydrocarbons (PAHs), and sulfur dioxide. Use the Writing Rubric for assessment.

State Education Standards
Texas Essential Knowledge and Skills for Career and Technical Education
§130.299. Firefighter I (One to Two Credits).
(5) The student describes the stages of a fire, the process of combustion, and the appropriate action to be taken for extinguishment. The student is expected to:
(A) describe the four products of combustion commonly found in structural fires that create a life hazard;
(7) The student analyzes the physical states of matter in which fuels are commonly found. The student is expected to:
(C) identify narcotic asphyxiant gases and irritants common in smoke.
The student analyzes the internal systems that sustain life in the human body and identifies the physical requirements of a self-contained breathing apparatus wearer. The student is expected to:

(A) explain the functions of the respiratory and the cardiovascular systems;

College and Career Readiness Standards
Science Standards
III. Foundation Skills: Scientific Applications of Communication
   C. Presentation of scientific/technical information
      1. Prepare and present scientific/technical information in appropriate formats for various audiences.
Common Products of Combustion Quiz

Multiple Choice:

1. _____ As a fuel burns, its chemical composition changes.
   A. True
   B. False

2. _____ Toxic smoke is produced by chemical reactions in fires.
   A. True
   B. False

3. _____ Of the three general products of combustion, light has the most impact on firefighters.
   A. True
   B. False

4. _____ Carbon monoxide (CO) is probably the most common product of combustion encountered in structure fires and is identified as the cause of death for civilians and firefighters without respiratory protection.
   A. True
   B. False

5. _____ Carbon dioxide (CO₂) is a simple asphyxiant and a respiratory stimulant.
   A. True
   B. False

6. _____ The primary function of the lungs is gas exchange. This process occurs where the bronchioles meet the pulmonary capillaries.
   A. True
   B. False

7. _____ Which of the following causes the most fire deaths?
   A. Extreme heat
   B. Toxic smoke
   C. Exhaustion
   D. Structural collapse

8. _____ Which of the following products of combustion acts as a chemical asphyxiant by binding with hemoglobin in the blood and is frequently identified as the cause of death in civilian fire fatalities?
   A. Methane
   B. Carbon monoxide (CO)
   C. Hydrogen cyanide (HCN)
   D. Carbon dioxide (CO₂)
9. _____Which of the following products of combustion is produced in the combustion of materials containing nitrogen and is a significant byproduct of the combustion of polyurethane foam?
   A. Methane
   B. Carbon monoxide (CO)
   C. Hydrogen cyanide (HCN)
   D. Carbon dioxide (CO₂)

10. _____Which of the following products of combustion is a product of complete combustion of organic materials and also acts as a respiratory stimulant?
   A. Methane
   B. Carbon monoxide (CO)
   C. Hydrogen cyanide (HCN)
   D. Carbon dioxide (CO₂)

**Short Answer:**

11. Name three products of combustion

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________

12. Name three products of combustion that are common (toxic) fire gases

   __________________________________________________________
   __________________________________________________________
   __________________________________________________________
Common Products of Combustion Quiz Key

1. A
2. A
3. B
4. A
5. A
6. B
7. B
8. B
9. C
10. D
11. Light, heat, heat energy, water vapor, carbon dioxide (CO$_2$), toxic gases, flammable gases, vapors, and/or particulates
12. Carbon monoxide (CO), hydrogen cyanide (HCN), carbon dioxide (CO$_2$)
Group Evaluation

Group 1

Did the group take the assignment seriously?
No
1 2 3 4 5 6 7 8 9 10
Yes

Could you tell what the group was trying to portray?
No
1 2 3 4 5 6 7 8 9 10
Yes

Was the group portrayal creative?
No
1 2 3 4 5 6 7 8 9 10
Yes

Did the group include the correct elements?
No
1 2 3 4 5 6 7 8 9 10
Yes

Would you like to see this group demonstrate its talent for you in the future?
No
1 2 3 4 5 6 7 8 9 10
Yes

Total Score_______

Group 2

Did the group take the assignment seriously?
No
1 2 3 4 5 6 7 8 9 10
Yes

Could you tell what the group was trying to portray?
No
1 2 3 4 5 6 7 8 9 10
Yes

Was the group portrayal creative?
No
1 2 3 4 5 6 7 8 9 10
Yes

Did the group include the correct elements?
No
1 2 3 4 5 6 7 8 9 10
Yes

Would you like to see this group demonstrate its talent for you in the future?
No
1 2 3 4 5 6 7 8 9 10
Yes

Total Score_______
**Group 3**

Did the group take the assignment seriously?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Could you tell what the group was trying to portray?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Was the group portrayal creative?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Did the group include the correct elements?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Would you like to see this group demonstrate its talent for you in the future?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Total Score_______

**Group 4**

Did the group take the assignment seriously?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Could you tell what the group was trying to portray?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Was the group portrayal creative?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Did the group include the correct elements?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Would you like to see this group demonstrate its talent for you in the future?  
No 1 2 3 4 5 6 7 8 9 10  
Yes

Total Score_______
**Group 5**

Did the group take the assignment seriously?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Could you tell what the group was trying to portray?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Was the group portrayal creative?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Did the group include the correct elements?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Would you like to see this group demonstrate its talent for you in the future?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Total Score_______

**Group 6**

Did the group take the assignment seriously?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Could you tell what the group was trying to portray?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Was the group portrayal creative?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Did the group include the correct elements?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Would you like to see this group demonstrate its talent for you in the future?  
No 1 2 3 4 5 6 7 8 9 10  Yes

Total Score_______
### Discussion Rubric

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<td>Participates in group discussion</td>
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<td>Encourages others to join the conversation</td>
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<td>Keeps the discussion progressing to achieve goals</td>
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<td>Shares thoughts actively while offering helpful recommendations to others</td>
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<td>Gives credit to others for their ideas</td>
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<td>Respects the opinions of others</td>
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<td>Involves others by asking questions or requesting input</td>
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<td>Expresses thoughts and ideas clearly and effectively</td>
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**Total Points (32 pts.)**

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<td>Follows directions</td>
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<td>Time management</td>
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<td>Student used time wisely and remained on task</td>
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<td>Student kept notes and materials in a neat,</td>
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<td>Student documented information in his or her</td>
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<td>own words and can accurately answer questions</td>
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<td>related to the information retrieved</td>
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<td>Student used a variety of methods and sources</td>
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<td>to gather information. Student took notes while</td>
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Comments:
## Presentation Rubric

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<td><strong>Topic/Content</strong></td>
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<td>• Topic discussed completely and in-depth</td>
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<td>• Includes properly cited sources (if used)</td>
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<td><strong>Creativity/Neatness</strong></td>
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<td>• Integrates a variety of multimedia effects to create a professional presentation (transition and graphics) or appropriate visual aid used</td>
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<td>• Title slide, table of contents, bibliography are included, using acceptable format</td>
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<td><strong>Mechanics</strong></td>
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<td>• Grammar, spelling, punctuation, and capitalization are correct</td>
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<td>• Image and font size are legible to the entire audience</td>
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<td><strong>Oral Presentation</strong></td>
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<td>• Communicates with enthusiasm and eye contact</td>
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<td>• Voice delivery and projection are dynamic and audible</td>
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<td><strong>Audience Interaction</strong></td>
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<td>• Presentation holds audience’s attention and relates a clear message</td>
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<td>• Clearly and effectively communicates the content throughout the presentation</td>
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**Total Points (20 pts.)**

Comments:
## Writing Rubric

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<td>The writing has all required parts from introduction to conclusion in smooth transition.</td>
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<td>The writing is interesting, supportive, and complete.</td>
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<td>The writing demonstrates that the writer comprehends the writing process.</td>
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<td>Accurate spelling, grammar, and punctuation</td>
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<td>The content of paragraphs emphasizes appropriate points.</td>
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<td>The writer shows an understanding of sentence structure, paragraphing, and punctuation.</td>
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<td>All sources and references are clearly and accurately documented.</td>
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**Total Points (28 pts.)**

Comments: