In this story, concepts such as vapor and external pressures, boiling point, the ideal gas law, and chemical reaction rates are emphasized.

It is 6 p.m. and the Clarksons are preparing dinner for their friends, Carol and Steve. Ben is a truck driver and has been taking some night classes at a local community college for enrichment. Ann also leads a busy life, working two jobs. She has decided that tonight, in the interest of time, she will try out the new pressure cooker she recently received for her birthday.

Ann: Honey, our guests are going to be here soon! Will you taste the beef stew? Let me know what you think so I can whip up a dessert quickly.

Ben: Yes, boss. Hmm... definitely undercooked. Carol and Steve won’t like that.


Ben: Did you forget to use the vent stopper?

Ann: Shoot, I sure did. What does it do anyway?

Ben: Do you really want to know? I just learned about the gas laws in my chem class, very interesting stuff.

Ann: Sure, tell me more about it.

Ben: All right. As you know, water normally boils at 100°C, so the temperature of water can’t exceed 100°C in an open vessel (like what’s used in conventional cooking). Under normal conditions (1 atmosphere [atm] external pressure at sea level), any food in water can’t be cooked at temperatures greater than 100°C. However, the boiling point of water varies with external pressures—water boils at a higher temperature when the external pressure is increased. So the higher pressure inside a pressure cooker lets the water boil at temperatures greater than 100°C. Make sense?

Ann: So when the external pressure is lowered, water boils at a lower temperature?

Ben: All right. A pressure cooker consists of a pot and lid, which are usually made of metals such as aluminum or stainless steel. The lid has a rubber ring to seal off the space between the lid and the pot, a safety valve made of low-melting-point alloy, a vent to allow steam to escape, and a detachable vent stopper or pressure regulator that sits on top of the vent throughout the cooking process. This pressure regulator generates extra force (pressure) in addition to the atmospheric pressure (1 atm), which allows water inside the pot to boil under a higher pressure and hence at a temperature higher than its normal boiling point (100°C). So, food can be cooked at a higher temperature (usually 125°C for most pres-
sure cookers). According to my chem teacher, generally, for every 10°C increase, chemical reaction rate doubles. However, without the stopper, such as in your case, because there was no extra external pressure, your beef stew was cooked at regular speed at 100°C.

**Ann:** I see. What are some of the other advantages of using a pressure cooker besides saving time?

**Ben:** Well, you use less fuel, and there’s better retention of certain nutrients due to less water required and shortened cooking time (up to 70% faster than with conventional cookers). In addition, toxins and microbes can be destroyed more efficiently at greater temperatures. The same logic applies to canning foods and autoclaving instruments.

**Ann:** Why have safety valves?

**Ben:** Well, if the vent is clogged with food, no steam can escape from the pot. Under such circumstances—a sealed and rigid container—continuous heating would cause the steam pressure to build up inside the pot, which can be very dangerous and may cause an explosion.

**Ann:** That’s not good.

**Ben:** Nope, it’s not. This can be explained by the ideal gas law: \( PV = nRT \), meaning when volume (\( V \)) and temperature (\( T \)) are constant, more gas particles (\( n \), numbers of moles of gas; mole is a counting unit used by chemists) generate higher pressure (\( P \); \( R \) is a constant, that is, ideal gas constant. The safety valve is used to prevent such dangerous conditions.

**Ann:** Wait, I know volume is constant because the cooker is made of metals. But did you say \( T \) is also constant?

**Ben:** Yes. At the beginning of boiling, although heat is constantly absorbed by water, it is used to convert liquid to gas, a physical state change; therefore, the water temperature remains constant.

**Ann:** I see. And how does the safety valve work?

**Ben:** After the vent is clogged up, the higher pressure, generated by the accumulated steam, in turn raises the boiling temperature, and both the water and steam get even hotter. Once the temperature inside the pot reaches the melting point of the valve, the valve melts right away in order to release the steam (\( n \) decreases) and the pressure (\( P \) decreases as well), thus preventing explosions. Some pressure cookers come with a small basket or guard underneath the vent to prevent any clogging from food.

**Ann:** Gotcha. Oh, I smell the aroma of the stew. Just in time!

### Questions

1. How does external pressure influence the boiling point of water?
2. How does a pressure cooker speed up the cooking?
3. According to Chef Robert Sevaly, pressure cookers “really are a timesaver, cutting your cooking time by three-fourths.” If a person spends an average of 10 hours cooking per week, how much money would be saved by using a pressure cooker in one year?
4. At a higher altitude (e.g., Mount Everest), why does it take longer to cook?
6. Why does a slow cooker cook slowly?
7. What are some other benefits of pressure cooking (other than saving time)?
8. Can you use a pressure cooker to cook dry food, such as breads or pancakes? Explain.
9. What is the air pressure inside the pot after the safety valve melts? Explain.
10. What is the advantage of using an autoclave (generates steam with high pressure and temperature) to sterilize surgical instruments rather than simply boiling them in water?
11. Why is induced hypothermia used for patients who are undergoing certain surgeries?
12. During the boiling process, although energy is continuously provided, the temperature of the water is constant. Explain where the energy goes.
13. Calculate the pressure, in mmHg, of 20.0 g oxygen gas, in a 50.0 L container at 25°C. (The value of \( R \) is 0.0821 L·atm/mol·K.)
14. A humidifier can be a burn hazard. Why does 100°C steam burn more severely than 100°C of water?

### Case teaching notes

College students all lead busy lives, but few students take advantage of the convenience of pressure cookers, much less understand how they work. This case study uses a daily cooking scenario to demonstrate how
the boiling point of water is directly related to the external pressures in order to reinforce the concepts of boiling and boiling point, apply ideal gas law, and relate chemical reaction rates with temperatures. It also extends its teaching to autoclaves used to destroy microorganisms and toxins in the medical field and promotes awareness of time and energy conservations benefiting students as well as the environment.

This case study can be used as a supplement for the gas law chapter in nonmajor general chemistry courses such as General Chemistry, Fundamentals of Chemistry, General, Organic and Biological Chemistry I, as well as Nutrition. It is also an informal writing assignment for any of these courses that are also designated as writing intensive.

Objectives

- Stimulate students’ interest in chemistry.
- Reinforce chemistry concepts and scientific thinking skills.
- Enhance the concept of vapor pressure of water.
- Emphasize that the boiling points of water vary with external pressures.
- Demonstrate that chemical reaction rates increase at higher temperatures.
- Apply the ideal gas law to explain a real-life scenario.
- Practice unit conversion skills.
- Create awareness of energy conservation in daily life.

Classroom management

A copy of the case and the data of boiling point of water under different pressures (Timberlake 2002; see Table 1) should be provided at the beginning of gas law lectures. After about one week, students can use one hour of lab time to examine the data and discuss the case among themselves in study groups (two to three people) and complete the questions associated with the case.

The discussion should be in the following areas: (1) What is boiling and boiling point? (2) What is vapor pressure of water? (3) What is external pressure? (4) How does the boiling point of water relate to external pressures and why? (5) How does a pressure cooker speed up the cooking process? (6) Why does a slow cooker cook food slowly? (7) Apply the ideal gas law to explain why a pressure cooker explodes when its vent is blocked.

Subsequently students can share their personal experience with pressure cooking, if any, within each study group. The teaching notes and an answer key to the questions are posted on the National Center for Case Study Teaching in Science at www.sciencecases.org/pressure_cooking/notes.asp.

TABLE 1

<table>
<thead>
<tr>
<th>Pressure (mmHg)</th>
<th>Boiling point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>270</td>
<td>70</td>
</tr>
<tr>
<td>467</td>
<td>87</td>
</tr>
<tr>
<td>630</td>
<td>93</td>
</tr>
<tr>
<td>752</td>
<td>99</td>
</tr>
<tr>
<td>760 (1 atm)</td>
<td>100</td>
</tr>
<tr>
<td>800</td>
<td>100.4</td>
</tr>
<tr>
<td>1075</td>
<td>110</td>
</tr>
<tr>
<td>1520 (2 atm)</td>
<td>120</td>
</tr>
<tr>
<td>2026</td>
<td>130</td>
</tr>
<tr>
<td>7600 (10 atm)</td>
<td>180</td>
</tr>
</tbody>
</table>

Note. atm = atmosphere

References


Resources


The benefits of using a pressure cooker http://missvickie.com/library/benefits.html


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