Vapor Pressure Curves

Why?

The vapor pressure of a substance depends on the temperature (higher temperature leads to higher vapor pressure). A liquid boils when the vapor pressure equals the atmospheric pressure. Water boils at 100 ^{o} C at sea level, but in Denver, Colorado, which is a mile high and has lower atmospheric pressure than at sea level, water boils at a different temperature. Certain substances, such as nail polish and paint, dry quickly because they have high vapor pressures.

Learning Objectives

- Understand the relationship between vapor pressure and temperature.
- Relate the vapor pressure of a substance to its boiling point.
- Use a vapor pressure curve to describe the relative strength of the intermolecular forces between the molecules of a substance.

Success Criteria

- Produce an accurate written description of vapor pressure and its origins.
- Identify the boiling point of liquids from vapor pressure curves.
- Infer the relative strength of intermolecular forces based on data in vapor pressure curves.

Resources

- Materials: ethanol, water, acetone, cotton balls

Prerequisites

- Vaporization
- Phase changes
- Graphing skills

Concepts and Vocabulary

Define the following terms in your own words.
- Vaporization
- Evaporation
- Boiling
- Normal boiling point
- Intermolecular forces of attraction

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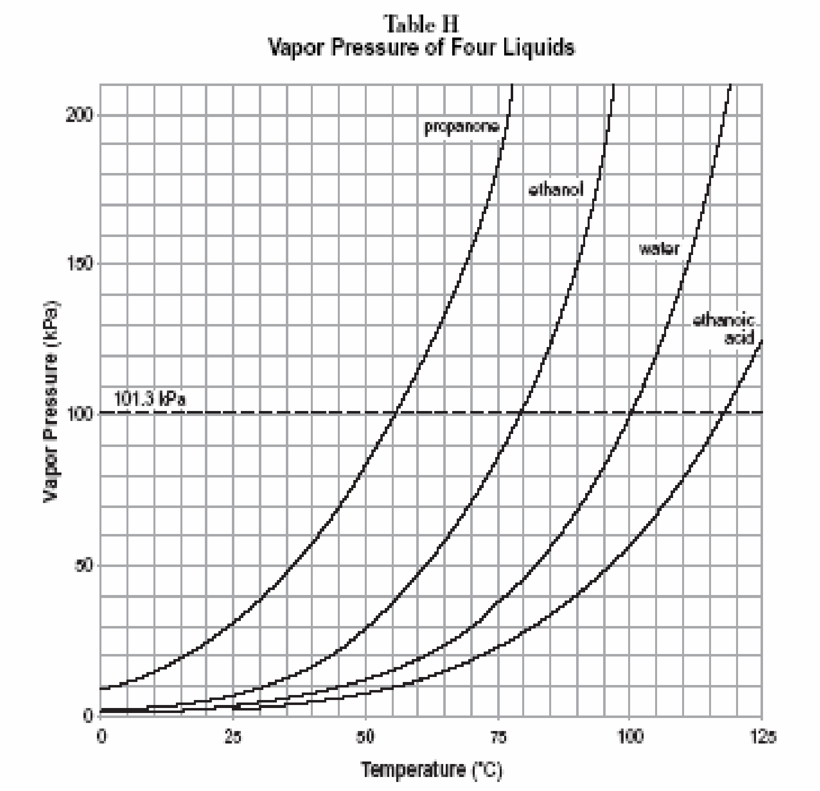
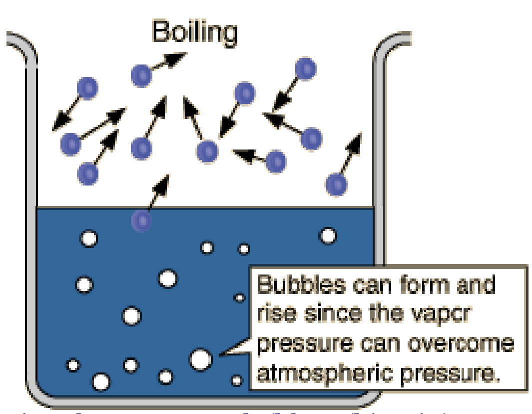
Model 1



(http://nysedregents.org/testing/reftable/archreftable/ChemRef1-7.pdf; Table H)

A liquid will boil when its vapor pressure equals atmospheric pressure. Water's normal boiling point is 100°C. At this temperature the vapor pressure of water is equal to 101.3 kPa, standard atmospheric pressure. If we were in a location with a different atmospheric pressure the boiling point would be different. For example, if the atmospheric pressure were 90 kPa, the boiling point of water would be 95^{o} C.



(http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/vappre.html)

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Key Questions

1. The vapor pressure curves of four liquids are shown in the graph in Model 1. What is plotted on the x-axis and what is plotted on the y-axis of the graph?

2. What happens to the vapor pressure of a substance when the temperature increases?

3. According to the information provided in Model 1, what determines the temperature at which a liquid boils?

4. What is the normal boiling point of propanone?

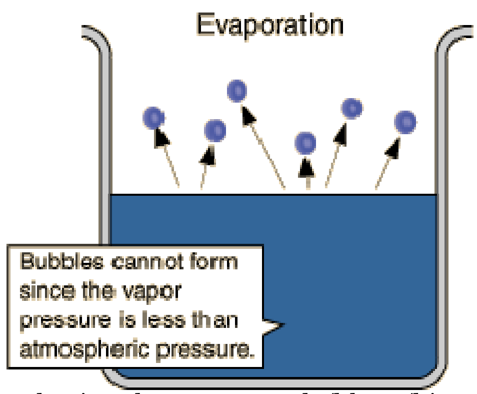
5. At what temperature will propanone boil if the atmospheric pressure is 70 kPa?

Exercise

1. List the four liquids in Model 1 in order of increasing vapor pressure at 60 ^{o}C.

Model 2

Evaporation, unlike vaporization, happens on the surface of liquids at all temperatures. This process is related to the strength of the forces holding the molecules in the liquid phase. The weaker the forces, the faster the molecules will escape from the liquid into the gas phase. A liquid with weak intermolecular forces will have a relatively large amount of vapor (gas phase) present above its surface.



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Task

Place an equal amount of ethanol, acetone (propanone), and water on three separate cotton balls. Wipe the cotton balls on the desk at the same time. Observe the relative rate of evaporation for the liquids. Record your observations below.

Observations:

Key Questions

1. Which liquid evaporated at the fastest rate?

2. Which liquid evaporated at the slowest rate?

3. Based on your observations, which liquid has the highest vapor pressure? Explain your answer.

4. Predict which of the three liquids used in this task would have the highest boiling point. Support your answer with an explanation.

5. Which of the three liquids has the strongest intermolecular forces of attraction? Support your answer with an explanation.

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6. How do the intermolecular forces in propanone compare to the intermolecular forces found in water? Support your answer with an explanation.

Applications

1. A thermometer is placed in a beaker of water at room temperature. The beaker, water, and thermometer are covered by a bell jar attached to a vacuum pump. The pump is turned on and the pressure inside the bell jar is reduced. Predict what would be observed inside the bell jar.

2. Based on your predictions, suggest a possible boiling point for the water in the bell jar by using the information on the vapor pressure curve in Model 1. (Specify both temperature and pressure.)

3. Suggest a reason why changes need to be made in the cooking time when eggs are boiled in a location with a high altitude such as Denver, when compared to the cooking time at a sea level location such as Miami. Support your answer with insight you have gained from this activity.

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