

**ChemActivity: Phase Changes and Intermolecular Forces**  
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Open [phet.colorado.edu](http://phet.colorado.edu), choose play with simulations, choose Chemistry Tab  
Open: States of Matter Basics HTML

Record all answers on a separate sheet of paper.

1. Draw a particulate diagram of a solid, liquid and gas,
  - a. Indicate which phase should have the molecules moving at the greatest speed.
  - b. Indicate the phase where the molecules are farthest apart.
  - c. Check your particulate drawings with the first option in the simulation: States (box on left in HTML version)
2. Choose the Phase Changes option, spend 2 minutes playing with the simulation.
3. Choose oxygen from the molecules on the left, record initial temperature of the model \_\_\_\_\_
4. Add heat until you notice a phase change (example: solid to liquid), Record the temperature \_\_\_\_\_
5. Add heat until you notice another phase change, Record the temperature \_\_\_\_\_
6. Reset the model, the melting point of oxygen is  $-219\text{ }^{\circ}\text{C}$  and the boiling point is  $-183\text{ }^{\circ}\text{C}$ ).
  - a. Convert both temperatures to K
  - b. Now increase the heat until the temperature reaches that melting point. How does this compare to your results in 4?
  - c. Add heat until the temperature is at the boiling point. How does this compare to your results in 5?
7. According to the simulation, which phase has the fastest moving molecules? Does this match your prediction in 1?
8. Reset the model, change the molecule to water, record the initial temperature \_\_\_\_\_
9. Add heat until you notice a phase change (example: solid to liquid), Record the temperature \_\_\_\_\_
10. Add heat until you notice another phase change, Record the temperature \_\_\_\_\_
11. Reset the model, the melting point of water is  $0.0\text{ }^{\circ}\text{C}$  and the boiling point is  $100.0\text{ }^{\circ}\text{C}$ .
  - a. Convert both temperatures to K
  - b. Increase the heat until the temperature reaches that melting point. How does this compare to your results in 9?
  - c. Add heat until the temperature is at the boiling point. How does this compare to your results in 10?

12. Which molecule, oxygen or water, melts at a lower temperature? Evaporates at a lower temperature?
13. Considering your answers to question 12, describe what you think is happening between the molecules of water compared to oxygen.

**STOP for mini-lecture on intermolecular forces**

14. What is an intermolecular force?

Force	Description	Found in polar and/or nonpolar molecules	Example

15. Using your answers from question 1, draw where the intermolecular forces would exist.
16. Using the three types of intermolecular forces, how does this explain your comparison of water to oxygen in the simulation?

**Energy and Phase Changes**

17. What are the phase changes between solid, liquid and gas? Record as many as you can here. (There are six.)

Using the information from questions 1-16, answer the following questions:

18. Does it take more heat (energy) to change from solid to liquid or liquid to gas? How do you know based on the data you took? Explain.
19. Draw a heating curve similar to the one show on the powerpoint slide. On a heating curve, diagonal lines indicate changes in temperature for a physical state, and horizontal lines (plateaus) indicate changes of state.
- Identify the phase(s) and phase changes present in each segment (A→B, B→C, etc.).
20. What is the specific heat (J/°C g) of liquid water? Remember that specific heat is the amount of heat that a substance is able to absorb to change the temperature of 1 gram of by 1 °C. Where can you find these values?
21. The amount of heat added to melt (freeze) or evaporate (condense) a substance can be determined by knowing the heat of fusion or vaporization and the amount of substance you have. See slide.

- a. How much energy takes to convert 1g solid water to 1g liquid water? This is known as the heat of fusion.
  - b. How much energy takes to convert 1g liquid water to 1g water vapor? This is known as the heat of vaporization.
  - c. Using the simulation, how can you show that it takes more energy to convert a liquid to a gas than a solid to a liquid?
22. On your heating curve of water, write in the heat of fusion, heat of vaporization and specific heat of liquid water on the correct segments.
23. Looking at the heating curve for water:
- a. When going through a phase change, does the temperature change?
  - b. Why is the horizontal line for boiling so much longer than melting?
  - c. What state(s) (phase) is the molecule in during a phase change? Give a real life example.
  - d. The temperature is constant during segment D→E even though energy is being added, if more energy is being added, where is it going?
24. Based on what you know about heating curve, what do you think a cooling curve looks like? An example might be a gas that condenses to liquid and is then frozen to a solid. Draw your prediction. See slide to check.

25. Using the table and information provided, answer the following questions

Molecule	Polarity of Molecule	Type of bond	Heat of Vaporization (J/g)	Heat of fusion (J/g)
Oxygen	Nonpolar	Covalent	214	14
Propane	Nonpolar	Covalent	336	18
Benzene	Nonpolar	Covalent	395	128
Acetic acid	Polar	Covalent	390	192
Ethanol	Polar	Covalent	841	109
Ammonia	Polar	Covalent	1380	351
Water	Polar	Covalent	2260	334
Sodium Chloride	Polar	Ionic	13000	518

- a. At room temperature, what phase do you think each of these compounds might in? How do you know? Consider your experiences with any of these molecules.
- b. Identify the type of attractive force in each compound (consider Lewis structure and polarity of each structure)
- c. Which intermolecular force is the strongest for the covalently bonded molecules? (An ionic bond is not an intermolecular force)
- d. Write a claim on how phase changes are affected by intermolecular forces. Support with evidence (data) from your simulation and the table above.