How do particles interact?

Why are we doing this?

All particles interact with one another to some extent. How they interact, the energy and force associated with those interactions, and the resulting physical and chemical changes are central concepts of chemistry. As such, it is important to consider how the kinetic energy of a substance impacts the spacing of the particles, i.e., the distance between those particles. Moreover, the distance between the particles also influences the potential energy of the substance. Substances tend to prefer low potential energy/high configuration states. In this activity, we will explore how to predict these factors and generate an explanatory model for various changes in state.

Your Learning Outcomes

You will be able to:

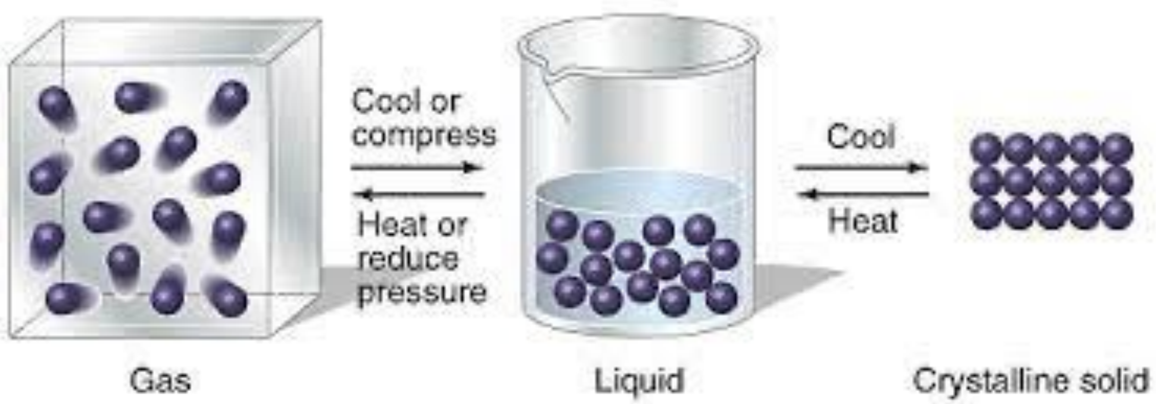
1. Describe how the potential energy between two particles changes as a function of the distance between the particles.
2. Describe how the potential energy between two particles changes as a function of the strength of the interaction force between the particles.
3. Describe, model, and predict how a system will change using a potential energy—configuration diagram.

The Plan

1. Assign roles*.
    a. ***Manager*** – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury; in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission and your TA must be notified of the absence.*

Model 1: Phase Changes



Information

Energy can be generally thought of as either kinetic energy or potential energy. Kinetic energy describes the energy of motion of the particles. Potential energy describes the force of the interactions between particles.

Critical Thinking Questions

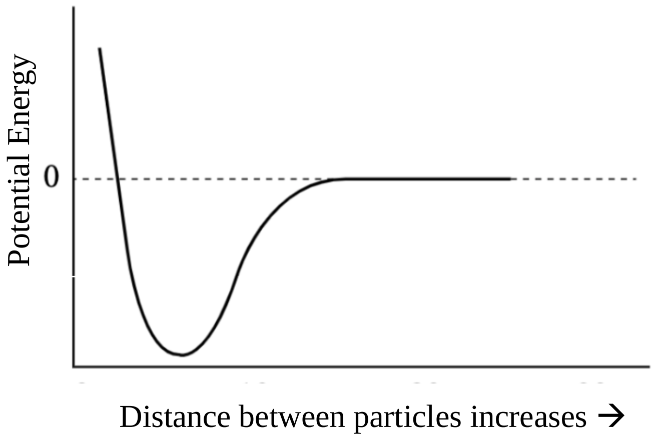
1. Which phase of matter has the least spacing between the particles?
   Solids

2. Which phase(s) of matter are confined to a definite volume?
   Solids and liquids

3. In which phase of matter is there the most potential for movement?
   Gases

4. Make a general state regarding how the kinetic energy of the particles changes as the state of matter changes.
   Solids have the least kinetic energy; liquids have an intermediate amount of kinetic energy; and gases have the most kinetic energy.

Model 2: The Potential Energy Curve

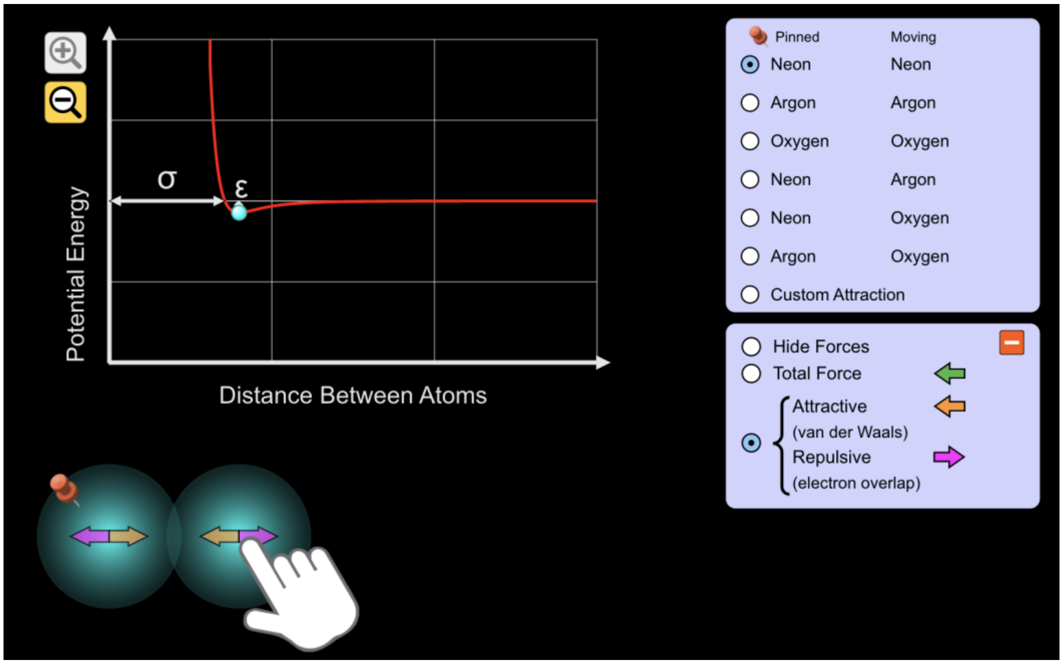


Critical Thinking Questions

5. Using the information provided in Model 2, describe the potential energy when the distance between particles is large.
The potential energy is approximately zero.

6. How does the potential energy change as the distance between the particles begins to decrease?
The potential energy becomes more negative.

Model 3: Observations of Potential Energy



Explore the simulation at
https://phet.colorado.edu/sims/html/atomic-interactions/latest/atomic-interactions_en.html

Information

Particles can experience attractive and repulsive forces. These forces vary as a function of the distance between the particles. These forces determine the potential energy between the two particles. Using the simulation, select 'Forces' and then select 'Attractive and Repulsive' to visualize these forces. You can change the distance between the particles by using the hand tool. You can also vary the type of particles that are interacting. Explore how the forces change as a function of distance and particle identity.

Critical Thinking Questions

7. Using Model 3, describe the attractive forces between particles when the distance between the particles is large.
   The attractive forces are very small.

8. How does the attractive forces change as the distance between the particles begins to decrease?
   The attractive forces begin to increase.

9. When do the repulsive forces become larger than the attractive forces?
   When the particles get too close to one another (i.e., closer that then distance at the minimum potential energy.

10. Are the interaction forces the same for all particles?
    No.

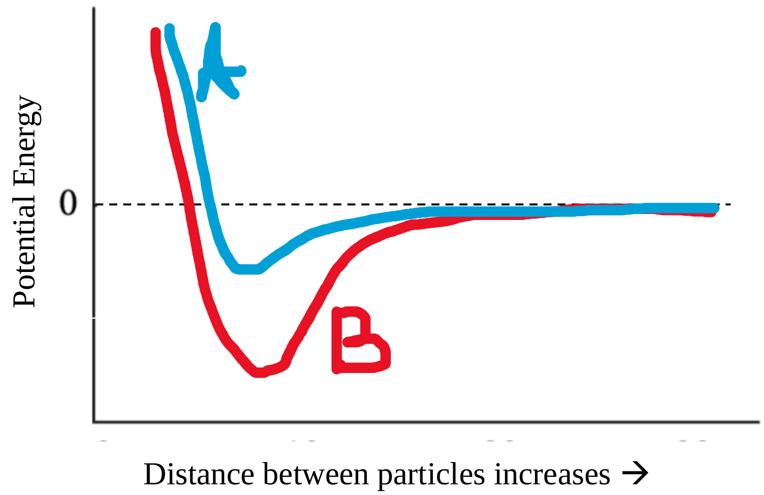
11. How does the potential energy change when the particles change?
    Different particles have more or less potential energy as they get closer.

12. The lowest potential energy describes the most stable arrangement of the two particles. Describe the attractive and repulsive forces at this point.
    At the minimum potential energy, the attractive and repulsive forces are equal to one another.

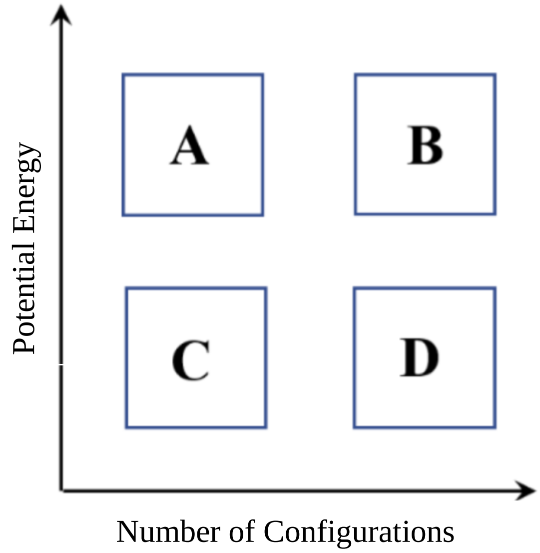
13. What happens if you pull one particle slightly away from the other particle when they are at the minimum potential energy position and then release it?
    The particle is pulled back towards the other and bounces back and forth around the minimum potential energy.

14. If you select 'Custom Attraction,' what happens to the potential energy when you increase the interaction strength of the two particles?
    The stronger the interaction strength, the lower (more negative) the potential energy becomes.

15. If two A particles have weak interaction forces, and two B particles have stronger interaction forces, sketch out a relative potential energy curve for both sets of particles on the same axes below.



Model 4: The Potential Energy—Configuration (PEC) Diagram



Information

The number of configurations refers to the number of possible ways the particles in a system can be arranged. Low potential energy is considered energetically stable (i.e., a preferred state). However, a higher number of configurations of a system can also led to a configurationally stable state. Together, these two factors can help us to predict is a system will prefer one state over another. If a system moves from high potential energy/low configurations (A) to low potential energy/high configurations (D), that will always be a favorable process. However, sometimes these factors can compete again one another.

Critical Thinking Questions

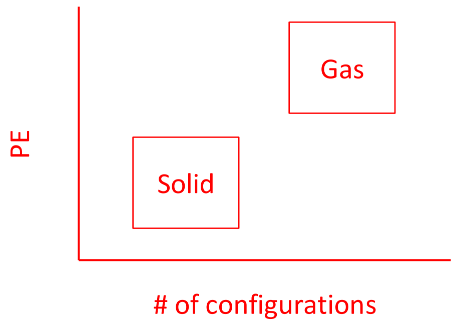
16. Are the particles in a solid confined to a specific region of space (refer to your answer to Question 2 above)?
    Yes

17. Are the particles in a gas confined to a specific region of space?
    No (they are only bound by the walls of the container they are in)

18. If the particles are restricted to a smaller region of space, then we say that the system has a lower number of possible configurations. As such, which state of matter, solid or gas, would have the higher number of possible configurations?
    Gas

19. Which state of matter, solid or gas, would have higher potential energy?
    Gas

20. Sketch a PEC diagram for sublimation.



Information

Sublimation is an example in which the potential energy and configuration factors compete against one another. Under high temperatures, the gas phase is the preferred state and the C→B transition is favorable (refer to Model 4). Under high pressures, the solid phase is the preferred state and the B→C transition is favorable.

Critical Thinking Questions

21. Why is the gas phase favored over the solid state under high temperature conditions?
    At higher temperatures, the particles in the system have more energy and more particles can have higher potential energy.
22. Why is the solid phase favored over the gas phase under high pressure conditions?
    At high pressure, the force exerted on the particles pushes them into a smaller region of space and the particles are more likely to adopt a solid-like configuration.