

HS-PS1-3

Students who demonstrate understanding can:

- HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.** [Clarification Statement: Emphasis is on understanding the strengths of forces between particles, not on naming specific intermolecular forces (such as dipole-dipole). Examples of particles could include ions, atoms, molecules, and networked materials (such as graphite). Examples of bulk properties of substances could include the melting point and boiling point, vapor pressure, and surface tension.] [Assessment Boundary: Assessment does not include Raoult's law calculations of vapor pressure.]

The performance expectation above was developed using the following elements from *A Framework for K-12 Science Education*:

| Science and Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts |
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| <p>Planning and Carrying Out Investigations Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.</p> <ul style="list-style-type: none"> Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. | <p>PS1.A: Structure and Properties of Matter</p> <ul style="list-style-type: none"> The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. | <p>Patterns</p> <ul style="list-style-type: none"> Different patterns may be observed at each of the scales at which a system is studied and can provide evidence for causality in explanations of phenomena. |

Observable features of the student performance by the end of the course:

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| 1 | Identifying the phenomenon to be investigated |
| | a Students describe* the phenomenon under investigation, which includes the following idea: the relationship between the measurable properties (e.g., melting point, boiling point, vapor pressure, surface tension) of a substance and the strength of the electrical forces between the particles of the substance. |
| 2 | Identifying the evidence to answer this question |
| | a Students develop an investigation plan and describe* the data that will be collected and the evidence to be derived from the data, including bulk properties of a substance (e.g., melting point and boiling point, volatility, surface tension) that would allow inferences to be made about the strength of electrical forces between particles. |
| | b Students describe* why the data about bulk properties would provide information about strength of the electrical forces between the particles of the chosen substances, including the following descriptions*: |
| | <ul style="list-style-type: none"> i. The spacing of the particles of the chosen substances can change as a result of the experimental procedure even if the identity of the particles does not change (e.g., when water is boiled the molecules are still present but further apart). ii. Thermal (kinetic) energy has an effect on the ability of the electrical attraction between particles to keep the particles close together. Thus, as more energy is added to the system, the forces of attraction between the particles can no longer keep the particles close together. iii. The patterns of interactions between particles at the molecular scale are reflected in the |

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| | | patterns of behavior at the macroscopic scale. |
| | iv. | Together, patterns observed at multiple scales can provide evidence of the causal relationships between the strength of the electrical forces between particles and the structure of substances at the bulk scale. |
| 3 | Planning for the investigation | |
| | a | In the investigation plan, students include: |
| | i. | A rationale for the choice of substances to compare and a description* of the composition of those substances at the atomic molecular scale. |
| | ii. | A description* of how the data will be collected, the number of trials, and the experimental set up and equipment required. |
| | b | Students describe* how the data will be collected, the number of trials, the experimental set up, and the equipment required. |
| 4 | Collecting the data | |
| | a | Students collect and record data — quantitative and/or qualitative — on the bulk properties of substances. |
| 5 | Refining the design | |
| | a | Students evaluate their investigation, including evaluation of: |
| | i. | Assessing the accuracy and precision of the data collected, as well as the limitations of the investigation; and |
| | ii. | The ability of the data to provide the evidence required. |
| | b | If necessary, students refine the plan to produce more accurate, precise, and useful data. |