Unit 2: How can a small spark start a huge explosion?

Investigation 1: What is happening when a spark occurs?

NGSS PEs:

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

MS-PS1-4. Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

Activity	What did we observe?	What did we figure out?	Model/Explanation	NGSS Dimensions
1: Can my finger start a fire?	• Lighting Bunsen burner with a spark from VdG	Start asking questions about energy and how it related to electrostatic phenomena	Start thinking about how we can add ideas of energy to the model for electrical interactions developed in Unit 1	DCI: *Energy: Definitions of energy. T*his is an introductory activity, there are no specific content ideas that students should develop in this activity. CCC: *Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. SEP: *Asking questions and defining problems:* Ask questions: • that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information. • that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
2: What happens to energy when objects collide?	• Rolling and colliding spheres of the same size and mass and different size and mass with different initial speeds and observe their motion	When mass is constant, speed can be used as an indicator of kinetic energy	• Develop model by defining system and surroundings, track energy transfer, energy conservation	DCI: Definitions of Energy: At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy. CCC: *Systems and system models:* Students investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. SEP: *Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the

	• Motion and energy simulation: investigate how energy of moving objects changes depending on mass and initial speed. • Bounce tennis ball and basketball together			relationships between systems or between components of a system.
3: If moving object have kinetic energy, do moving atoms have kinetic energy?	• Observe the speed of spreading food coloring in water at different temperatures • Particle diffusion simulation	Speed of particle motion is related to temperature of the substance: the higher the temperature, the larger the speed	Model of electrical interactions at the atomic level will relate thermal energy to kinetic energy	DCI: *Definitions of energy:* These relationships are better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of particles). CCC: *Energy and Matter:* They [students] can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. SEPs: *Developing and Using Models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system
4: If energy cannot go away, why don't things move forever?	• Observe the pendulum from when it starts until it stops swinging • Ball and clay demo to observe difference in the shape of the clay when ball is dropped on it • Pendulum and energy simulation	Potential energy is different from kinetic energy	• Energy is useful to track changes in systems. • Energy transfer • Energy conversion • Conservation of energy • The idea that energy is either associated with motion (kinetic	DCI: *Conservation of Energy and Energy Transfer* • Conservation of energy means that the total change of energy in any system is always equal to the total energy transferred into or out of the system. • Energy cannot be created or destroyed, but it can be transported from one place to another and transferred between systems. CCC: *Energy and Matter:* They [students] can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. SEPs: *Constructing explanations and designing solutions:* Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations,

			energy) or stored (potential energy)	models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

CREATE for STEM Institute

Next Generation Project-Based Learning

Investigation 2: Where does the energy of a spark come from?

NGSS PEs:

MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

HS-PS3-4. Plan and conduct an investigation to provide evidence that the transfer of thermal energy when two components of different temperature are combined within a closed system results in a more uniform energy distribution among the components in the system (second law of thermodynamics).

Activity	What did we observe?	What did we figure out?	Model/Explanation	NGSS Dimensions
1: How does potential energy change when things are pushed or pulled?	• Explore stretching and compressing spring • Use spring to push a toy car or a marble • Energy changes in spring simulation	Applying a force to move something from a stable state increases the potential energy of the system.	○ Energy can transfer from place to place. ○ Energy can convert from one form to another. ○ NOTE: The model involves the energy of the system and its surroundings.	DCI: *Conservation of energy and energy transfer:* [Energy is] better understood at the microscopic scale, at which all of the different manifestations of energy can be modeled as a combination of energy associated with the motion of particles and energy associated with the configuration (relative position of the particles). CCC: *Cause and effect:* Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors SEP: *Analyzing and interpreting data:* Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
2: Where does the energy that was used to charge the VdG generator go?	• Arrange the magnets so that they repel each other, and try to push them together. • Compare pushing the magnets together to pushing on both ends of a spring to compress it. • Electric charge and energy simulation	• Gravitational, magnetic, and electric potential energy are stored in fields. • Potential energy only exists in a system made of two or more interacting objects.	Model of electrostatic interactions includes ideas of energy and Coulombic relationship (relationship between distance, amount of charge, and generated attractive/repulsive force)	DCI: *Definitions of energy:* [Potential energy can be understood as] energy associated with the configuration (relative positions of the particles). In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). CCC: *Systems and system models:* Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. SEP: *Developing and using models:*

				Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
3: Why is lightning so much bigger than a spark from VdG?	• Stretch and compress two springs of different length • Compare the strengths of magnet with different strengths by testing how difficult it is to separate the magnet from the paper clip • Factors affecting potential energy in a magnetic field simulation	• Using a force to change the relative positions of interacting objects in a system changes the amount of potential energy stored in the system/field. • The electric field is affected by changing the amount of charge and the position of the charged objects (distance)	• The larger the amount of charge on the two interacting objects, the larger the amount of potential energy stored in the field formed by the objects • The amount of potential energy stored in the field of charged interacting objects depends on the type of charge and distance between them (see target model from investigation for model info)	DCI: *Definitions of energy:* In some cases, the relative position energy can be thought of as stored in fields (which mediate interactions between particles). CCC: *Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. SEP: *Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
4: Why do I get shocked if I am too close to the VdG?	• Drop a pencil on the floor and try to make it stand • Charge, distance and potential energy simulation • Sparks on the VdG simulation	Systems tend to move toward more stable states. A more stable state means the energy is more evenly distributed and the potential energy has been minimized. This investigation focuses	• Model includes that systems tend to move towards minimum potential energy state	*DCI: Conservation of energy and energy transfer:* Uncontrolled systems always evolve toward more stable states—that is, toward more uniform energy distribution (e.g., water flows downhill, objects hotter than their surrounding environment cool down). *CCC: Cause and effect:* Students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. *SEP: Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

		only on minimizing the potential energy.		

Investigation 3: Why does an explosion not start spontaneously?				
NGSS PEs: MS-PS1-1 Develop models to describe the atomic composition of simple molecules and extended structures. HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.				
Activity	**What did we observe?**	**What did we figure out?**	**Model/Explanation**	**NGSS Dimensions**
1: What makes substances different from each other?	Measure and use properties to characterize and distinguish between substances.	Substances have distinctive properties that can be used to identify them	A molecule is a collection of two or more atoms that are linked together. Molecules of the same substance have the same composition and ratio of atoms. Molecular geometry and the arrangement of atoms within a molecule is outside the scope of this investigation.	DCI: *Structure and properties of matter:* Substances are made from different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. CCC: *Structure and Function:* Students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal a system's function and/or solve a problem. SEP: *Analyzing and interpreting data:* Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. *Developing and using models:* Students will develop and/or use model to predict and /or describe phenomena
2: What holds the atoms of a molecule together?	• Atoms forming a bond simulation • Representations of atoms that are bonded together	Chemical bond forms at a distance between atoms where attractive and repulsive interactions are balanced out and the electron clouds overlap	• In a stable molecule, the repulsive force between the positive nuclei is balanced by the attractive force between the positive nuclei and the negatively charged electrons. • When the attractive and repulsive forces between two atoms are	DCI: *Types of Interactions:* Attraction and repulsion between electric charges at the atomic scale explain the structure, properties, and transformations of matter, as well as the contact forces between material objects. *Structure and properties of matter:* The structure and interactions of matter at the bulk scale are determined by electrical forces within and between atoms. CCC: *Cause and Effect:* Cause and effect students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems SEP: *Developing and using models:*

			balanced, and the electron probability distribution of the atoms overlaps significantly between them, a bond forms between the atoms. • Atoms in a stable molecule are held together by the sharing of electrons.	Students will develop and/or use model to predict and /or describe phenomena.
3: When atoms get close to each other, what happens to their potential energy?	• Atoms forming a bond and potential energy change simulation	• A molecule has lower potential energy than the same set of individual atoms. • *Binding energy* is the difference in potential energy between the "optimal distance" where atoms form a molecule and a "too far distance" where no interaction occurs between them. Atoms in a stable molecule are held together by the sharing of electrons.	Chemical bond forms at a distance between atoms where attractive and repulsive interactions are balanced out and potential energy of the system is minimized	DCI: *Structure and properties of matter:* A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. CCC: *Cause and Effect:* Cause and effect students suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems SEP: *Developing and using models:* Students will develop and/or use model to predict and /or describe phenomena
4: How are bonds formed and broken?	• Colliding billiard balls to observe the motion and what happens during the collision	• When a bond is formed, potential energy decreases so energy is transferred to the surroundings • When a bond is broken, energy is absorbed. • The amount of energy that is needed to break a bond is exactly equal to the binding energy of the molecule. • Use conservation of energy to explain that energy conversion takes	Students will model and explain bond making/breaking processes using ideas related to electrostatic interactions between components of atoms	DCI: *Structure and properties of matter:* Matter of any type can be subdivided into particles that are too small to see, but even then, the matter still exists and can be detected by other means. CCC: *Scale, Proportion, and Quantity:* Students recognize that patterns observable at one scale may not be observable or exist at other scales and that some systems can only be studied indirectly as they are too small to observe directly. SEP: *Engaging in argument from evidence:*

	• Atoms colliding to form a bond simulation • Energy changes when bonds break simulation	place between potential energy and other forms of energy, and that energy transfer also occurs, when a molecule forms or breaks.	and associated energy changes.	• Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. • Make and defend a claim based on the effectiveness of a design solution that reflects scientific knowledge

Investigation 4: Where does all the energy of an explosion come from?

NGSS PEs:

HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.

HS-PS1-5. Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs. [*Clarification Statement*: Emphasis is on student reasoning that focuses on the number and energy of collisions between molecules.]

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motion of particles (objects) and energy associated with the relative positions of particles (objects).

Activity	What did we observe?	What did we figure out?	Model/Explanation	NGSS Dimensions
1: What energy changes occur during an explosion?	• Hydrogen and oxygen forming a bond simulation • Igniting a balloon filled with mixture of hydrogen and oxygen	• Flame is needed to start reaction between hydrogen and oxygen in the balloon	• Energy is required to form bonds	DCI: *Structure and properties of matter:* A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart CCC: *Energy and matter:* [Students] can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. SEP: *Asking questions and defining problems:* Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
2: What happens to atoms in chemical reactions?	• Copper II chloride and aluminum reaction • Electrolysis • Still wool demonstration	Molecules break apart and the same atoms rearrange and form new bonds in a reaction. No reaction mechanism included.	Molecules break apart and the same atoms rearrange and form new bonds in a reaction. No reaction mechanism.	DCI: *Chemical reactions:* The fact that atoms are conserved, together with knowledge of the chemical properties of the elements involved, can be used to describe and predict chemical reactions. CCC: *Structure and function:* Students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. SEP: *Developing and using models:* Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

3: What changes in energy occur when atoms rearrange during a chemical reaction?	• Hydrogen peroxide lab: hydrogen peroxide decomposition goes much faster in warm water (more bubbles build up) than in room temperature water. • Bond forming simulation • Bond breaking simulation • Electrolysis of water lab	Energy is required to break forms, you need to put energy into the system to form bonds. When bonds form, energy is released. Different atoms release different amount of energy when bonds form.	Energy is released when bonds form. For different sets of atoms, different amount of energy is released when bonds form	DCI: *Structure and properties of matter:* A stable molecule has less energy than the same set of atoms separated; one must provide at least this energy in order to take the molecule apart. *Chemical reactions:* Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. CCC: *Energy and matter:* Students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. *Patterns:* Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. SEP: *Developing and using models:* Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. *Analyze and interpret data:* Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
4: How does a spark trigger an explosion?	• Hydrogen/oxygen chain reaction simulation •	Developed final model for the DQ	If the properties of the substances before and after a process differ, then new substances have formed and a chemical reaction has occurred. Breaking bonds requires an input of energy. When bonds form, the potential energy decreases; the available energy is used to continue the reaction or is transferred to the surroundings, or both. When a chemical reaction transfers energy to the surroundings after the product	DCI: *Chemical reactions:* Chemical processes, their rates, and whether or not energy is stored or released can be understood in terms of the collisions of molecules and the rearrangements of atoms into new molecules, with consequent changes in the sum of all bond energies in the set of molecules that are matched by changes in kinetic energy. *CCC: Cause and effect:* [Students] suggest cause and effect relationship to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms in the system. SEP: *Constructing explanations:*

			molecules have formed, it is an *exothermic reaction*; if energy must continually be transferred in from the surroundings for the chemical reaction to continue, it is an *endothermic reaction*.	Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.