The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 1: WHAT IS A CHEMICAL REACTION?

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)

Students observe a demonstration of a burning candle to begin to learn about reactants and products in chemical reactions. Students see a molecular model animation of a combustion reaction and note that the atoms in the molecules of the reactants rearrange to form the molecules of the products. Students see that the total number of each type of atom is conserved.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Engaging in argument from evidence

Students investigate the question: Where do the atoms in the products of a chemical reaction come from? In addition to seeing the burning candle and a molecular model animation, students make their own cut-outs of atoms and use them to model the rearrangement of atoms from reactants to products in a chemical reaction. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)

Students use molecular-level models of reactants forming products to explain how the interaction and rearrangement of atoms in a combustion reaction results in the macroscopic observation of light, heat, and the formation of the products of the reaction.

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CHAPTER 6, LESSON 2: CONTROLLING THE AMOUNT OF PRODUCTS IN A CHEMICAL REACTION

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)

Students combine vinegar and baking soda and see the production of a gas. They look at the chemical equation for the reaction and realize that the gas is carbon dioxide. Students count the type and number of atoms in the reactants and products and see that they are the same.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Analyzing and interpreting data

Engaging in argument from evidence

Students investigate the question: How can you make just the right amount of foam that rises to the top of the graduated cylinder without overflowing? Students plan and conduct an investigation using vinegar and baking soda to see how accurately they can adjust the amount of reactants to form a certain amount of gas. Students see that changing the

amount of either or both reactants can affect the amount of products produced. Students discuss the idea that adding a large excess of one reactant will have a limited effect on increasing the amount of products. Students look at an illustrated version of the chemical equation for the reaction along with an equation using the chemical formulas to get a better idea of what the formulas actually represent. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)

Students use illustrations of molecules along with their formulas to explain how the interaction and rearrangement of atoms in the baking soda-and-vinegar reaction results in the macroscopic observation of the production of more gas or less gas depending on the amount of reactants used.

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Chapter 6, Lesson 3: Forming a Precipitate

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)

Students combine a baking soda solution with a calcium chloride solution and observe a gas produced and a white color in the solution. Students filter the solution and see a solid white precipitate. They look at the chemical equation for the reaction and realize that the gas is carbon dioxide, and that the solid is calcium carbonate or chalk. Students count the type and number of atoms in the reactants and products and see that they are the same.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Engaging in argument from evidence

Students investigate the question: How do you know that a precipitate is formed in a chemical reaction? Students conduct a chemical reaction to investigate the production of a precipitate and how to separate it from the other products of the reaction. Students see observable evidence of carbon dioxide gas and calcium carbonate (chalk) as products of their reaction. Students look at a molecular model illustration of the chemical equation for the reaction along with an equation using the chemical formulas to get a better idea

of what the formulas actually represent. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)

Students use illustrations of molecules along with their formulas to explain how the interaction and rearrangement of atoms in the reaction between solutions of baking soda and calcium chloride results in the macroscopic observation of carbon dioxide gas, a calcium carbonate precipitate, and salt.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 4: TEMPERATURE AND THE RATE OF A CHEMICAL REACTION

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)

Students use solutions of baking soda and calcium chloride that they used in the last lesson. Students see that using warmer reactants makes the chemical reaction happen faster than using colder reactants. Students are introduced to the idea that molecules need to collide with enough energy for atoms to rearrange to form the products.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Engaging in argument from evidence

Students investigate the question: Does the temperature of the reactants affect the rate of the chemical reaction? Students plan and conduct an investigation to see if a chemical reaction happens faster if the reactants are heated. Students see an animated model of a reaction showing that molecules need to collide with enough speed for atoms to rearrange and make products. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)

Students use a molecular model animation of molecules colliding to explain how heating affects the speed of molecules, and how the speed of the molecules affects the macroscopic observation of differences in the rate of a chemical reaction.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 5: A CATALYST AND THE RATE OF REACTION

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

- PS1.A: Structure and Properties of Matter
- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)
- Some chemical reactions release energy; others store energy (MS-PS1-6)

Students learn that hydrogen peroxide molecules react with each other to produce water and oxygen gas. They see that the total number of each type of atom in the reactants is also in the products. Students also see that yeast catalyzes the reaction and that the reaction releases energy.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Engaging in argument from evidence

Students investigate the question: Can yeast catalyze the decomposition of hydrogen peroxide? Students plan and conduct an investigation to see if the catalyst in yeast has an effect on the rate at which hydrogen peroxide molecules react with each other to form oxygen gas. Students use the amount of oxygen produced as a measure of the rate of the reaction and see that adding a catalyst does increase the rate of the reaction. Students see a molecular model illustration of the reaction showing that oxygen gas is produced.

Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)

Students use a molecular model of a reaction between hydrogen peroxide molecules, and an explanation of how catalysts work, to explain how adding a catalyst affects the macroscopic observation of the increased rate of reaction.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 6: USING CHEMICAL CHANGE TO IDENTIFY AN UNKNOWN

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)

Students see that each of four substances has a different set of reactions with four different test liquids. Students discover that substances react chemically in characteristic ways. Students use their observations to identify an unknown substance.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Analyzing and interpreting data

Engaging in argument from evidence

Students investigate the question: Can the characteristic way substances react be used to identify an unknown powder? Students plan and conduct an investigation to test four known substances with four different test liquids to identify an unknown substance. After making and recording their observations, students conduct the same tests on the unknown substance and are able to identify the unknown. Students see molecular model illustrations of the different substances and see that they are composed of different atoms arranged in a specific way. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Students reason that the different atoms composing different substances results in their characteristic observable reactions when test liquids are added to them.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 7: ENERGY CHANGES IN CHEMICAL REACTIONS

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)
- Some chemical reactions release energy; others store energy (MS-PS1-6)

Students see that a reaction between baking soda and vinegar absorbs energy and gets colder (endothermic), and that a reaction between baking soda solution and calcium chloride releases energy and gets warmer (exothermic). Students also see that the total number of each type of atom in the reactants is also in the products.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Engaging in argument from evidence

Students investigate the question: Does the temperature change during a chemical reaction between vinegar and baking soda, and between calcium chloride and a baking soda solution? Students conduct an investigation and see that one reaction results in a temperature increase and the other reaction results in a temperature decrease. Students use a molecular model animation to begin to develop the concept that energy is absorbed when

bonds are broken and energy is released when new bonds are formed. The net amount, either absorbed or released, determines whether a reaction is endothermic or exothermic. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Energy and Matter

- Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5)
- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6)

Students use molecular-level models of atoms breaking bonds and making bonds to explain how these sub-microscopic processes affect the macroscopic observable characteristic of an increase or decrease in temperature during a chemical reaction.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 8: PH AND COLOR CHANGE

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)

Students see that an acid causes a pH indicator to turn from green to red and that a base makes the indicator change from green to purple. A molecular animation shows how water molecules and acid, base, and indicator molecules interact to produce a color change. Students see that acids and bases react chemically in characteristic ways.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Analyzing and interpreting data

Engaging in argument from evidence

Students investigate the question: How does the concentration of citric acid affect the color of universal indicator? Students conduct an investigation to see how the concentration of citric acid solution and the concentration of sodium carbonate solution affect the pH and color of universal indicator solution. Students use a molecular model animation showing the transfer of protons between water molecules and acid, base, and indicator molecules that result in a color change. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Students use molecular model animations of water, indicator, acid, and base to explain how these substances interact to cause the observable color changes of the indicator.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 9: NEUTRALIZING ACIDS AND BASES

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)

Students use sodium carbonate (base) to neutralize a citric acid solution. They also use a citric acid solution to neutralize a sodium carbonate solution. Students see that different substances are made from different atoms and react chemically in characteristic ways.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Analyzing and interpreting data

Engaging in argument from evidence

Students investigate the question: How many more drops of solution does it take to neutralize a more concentrated acidic or basic solution? Students use a base to neutralize two acidic solutions and see that it takes more base to neutralize the more concentrated acidic solution. Students then use an acid to neutralize two basic solutions to discover which of two solutions is more concentrated. In both cases, students use a molecular model of proton transfer to understand the process of neutralizing. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Students use molecular model animations of water, indicator, acid, and base to explain how these substances interact to cause the observable phenomena of an acid neutralizing a base, and a base neutralizing an acid.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 10: CARBON DIOXIDE CAN MAKE A SOLUTION ACIDIC

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

DISCIPLINARY CORE IDEAS

PS1.A: Structure and Properties of Matter

- Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. (MS-PS1-2), (MS-PS1-5)
- The total number of each type of atom is conserved and thus the mass does not change. (MS-PS1-5)

Students see that carbon dioxide from different sources results in a color change of a pH indicator in water. Students learn that carbon dioxide and water combine to form the weak acid, carbonic acid. Students look at the chemical equation for the reaction and see that the type and number of atoms in the reactants is the same as in the products.

SCIENCE AND ENGINEERING PRACTICES

Developing and Using Models

- Develop a model to describe unobservable mechanisms. (MS-PS3-2)

Planning and carrying out investigations

Engaging in argument from evidence

Students investigate the question: Will carbon dioxide from different sources cause water to become acidic? Students conduct an investigation and see that carbon dioxide from exhaled breath, club soda, and from a vinegar-and-baking soda reaction all cause water to become acidic. Students look at a molecular model illustration of the chemical reaction and see that water and carbon dioxide molecules react to form carbonic acid. Students use and further develop this molecular model and apply it to evidence they have observed to explain their observations on the molecular level and to answer the question to investigate.

CROSSCUTTING CONCEPTS

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-PS1-4)

Scale, Proportion, and Quantity

- Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1)

Students use molecular-level models to explain how the reaction between water and carbon dioxide molecules affect the macroscopic observable characteristic of an indicator changing color and water becoming more acidic. Students relate this process to an even larger scale when considering how this reaction affects ocean acidification.

The Next Generation Science Standards (NGSS)

CHAPTER 6, LESSON 11: CHEMICAL REACTIONS AND ENGINEERING DESIGN

MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

DISCIPLINARY CORE IDEAS

PS1.B: Chemical Reactions

Some chemical reactions release energy; others store energy. (MS-PS1-6)

ETS1.A: Defining and Delimiting Engineering Problems

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge likely to limit possible solutions. (MS-ETS1-1)

ETS-1-B: Developing Possible Solutions

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (MS-ETS1-2), (MS-ETS1-3)
- Models of all kinds are important for testing solutions. (MS-ETS1-4)

ETS1.C: Optimizing the Design Solution

- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

  Students are presented with the problem of using a chemical reaction to create a device to incubate snake eggs at a specific temperature. Students discuss the specifications or criteria for the device as well as the limitations of the materials and chemical process, or constraints. Students learn to test, measure, and analyze their results in order to refine the reaction. They also learn how to take different factors into consideration as they optimize the design.

SCIENCE AND ENGINEERING PRACTICES

Constructing Explanations and Designing Solutions

- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.

(MS-PS1-6) Planning and carrying out investigations

Asking Questions and Defining Problems

- Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (MS-ETS1-1)

Developing and Using Models

- Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (MS-ETS1-4)

Engaging in Argument from Evidence

- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria. (MS-ETS1-2)

  Students create a prototype model of a device to incubate a snake egg at a specific temperature range. They conduct trials adjusting the concentrations in a reaction between baking soda solution and calcium chloride to achieve the specific temperature range and to inflate a zip-closing plastic bag without popping. Students then consider different factors regarding insulation and heat transfer to optimize the design of the device.

CROSSCUTTING CONCEPTS

Energy and Matter

- The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6)

  In this lesson, students see that a chemical reaction can release energy and that the energy can be used in a practical way. After discovering a combination of reactants that produces the required temperature range, students need to consider how to insulate the device against excessive heat loss through heat transfer. Students consider using a Styrofoam cup or wrapping the cup with an insulating material. They may also consider designing a lid to reduce loss of heat through heat transfer.

