Hot on the Trail

1.1 Welcome

Notes:

Welcome to “Hot on the Trail,” an online science tutorial for students like you.
1.2 Objective

You will learn about how temperature affects chemical changes.

Notes:

In this tutorial you will investigate how temperature affects chemical changes. In your investigation you will first review temperature and then learn its role in chemical reactions.
Notes:

We are all aware of the temperature of objects; hot, warm, or cold. You probably have looked at the temperature outside when deciding what to wear for the day, but what exactly is temperature? For a scientist like yourself, it would be helpful to have a definition of the term.

Temperature is the degree or intensity of the amount of heat present in a material whether it be a solid, liquid, or gas. In other words, temperature measures the amount of heat in any substance.

So, what is heat? Heat is a form of energy related to how fast atoms or molecules move in a material. This energy of motion is called kinetic energy. Higher temperatures mean the atoms in that material are moving faster. On the other hand, cooler temperatures mean the molecules in a substance are moving slower.
1.4 Prior Knowledge – Temperature Scales

Notes:

There are three temperature scales that are used in the world: Fahrenheit, Celsius, and Kelvin. The Fahrenheit Scale is used in the United States and is most likely the temperature scale you use on a daily basis. The weather report on the news typically uses the Fahrenheit Scale to report the temperature outside for a particular day. Measurements are given as degrees “F”.

The Celsius Scale is used in the sciences and many other countries. The Celsius scale is sometimes referred to as the centigrade scale. In the Celsius Scale water freezes at zero degrees Celsius and boils at one hundred degrees Celsius. Measurements in Celsius are reported as degrees “C”. The Kelvin Scale is the temperature scale that has been adopted by the International System of Measurement and is represented by the letter ‘K’.

Click on the images of ice, water, and steam to see equivalent measurement of temperature in each scale.
1.5 Practice 1

Match the terms in the drop-down menu with the correct definitions.

<table>
<thead>
<tr>
<th>Correct</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>A measure of the amount of heat present in a substance.</td>
<td>Temperature</td>
</tr>
<tr>
<td>Energy related to the average motion of atoms and molecules.</td>
<td>Heat</td>
</tr>
<tr>
<td>Temperature scale used in science where water freezes at zero degrees and boils at 100 degrees.</td>
<td>Celsius</td>
</tr>
</tbody>
</table>

Notes:

Try to match the appropriate term with its definition.

Feedback when correct:

Excellent! You knew that temperature is a measure of heat and heat is related to the speed of atoms and molecules in a substance. You also know that Celsius is a temperature scale used in science.

Feedback when incorrect:

You made a good attempt. Temperature is a measure of heat. Heat is related to the movement of atoms and molecules in a substance. Celsius is a temperature scale used in science.
1.6 What is a Chemical Reaction?

Notes:

You may already know that everything in the universe consists of a finite number of elements. These elements combine to form every substance we know of. All around you there are different substances on the ground, air, food and even that make up you. Elements combine or bond into molecules of all different kinds. Molecules make up everything. The air you breathe is a solution of oxygen, nitrogen, carbon dioxide, water and more. When different elements or molecules bond with one another, we call these chemical reactions.

A chemical reaction occurs when two or more substances combine in a way that their atoms actually rearrange into completely different substances. A great example of a chemical reaction is photosynthesis. Carbon dioxide and water react along with energy from the sun to form glucose and oxygen. The molecules rearrange to form completely new substances. There are many factors that contribute to whether a chemical reaction takes place.
1.7 Factors That Affect a Chemical Reaction

Notes:

The factors that affect the rate of a chemical reaction include: the concentration of the substance, the phase and surface area of the substances, the type of solvent used, the use of a catalyst, and finally, the temperature of the substances. Let’s look at each of these briefly to understand a bit more about these factors.

The concentration of a substance means that the solution has a high amount of the chemical or reactant. If we were to going to mix vinegar and baking soda we would get a great reaction. However if we diluted the vinegar with a good amount of water first, the reaction would occur much more slowly.

Surface area and phase of a substance also affect rate of a chemical reaction. They are related based on how much of the substance is available for combining. A fine powder of substance has a much larger surface area than a block of the same substance and so will react much more quickly with another substance. This is similar to why the phase of the substance would also affect reaction rates. Liquid forms of a substance will mix more easily than if the substances were solids.

Solvents are a solution of ingredients already combined with another. A solvent can combine with another chemical faster or slower depending on the type of solvent.

A catalyst is a chemical that is used to help speed up a chemical reaction. The neat thing about catalysts is they are not used up in a chemical reaction but are available again after the reaction is complete. In your body these are called enzymes and are extremely important.

And finally, temperature is a factor that affects the rate of chemical reactions. We will learn about this factor more thoroughly as we proceed in this tutorial.
**1.8 Practice 2**

**Notes:**
Match the factor that contributes to a chemical reaction to its definition.

**Feedback when correct:**
Excellent! While these all are ways to increase the rate of reaction, it is important to understand their meanings!

**Feedback when incorrect:**
The correct answers are shown on the slide. All four of these are factors that can affect the rate of chemical reactions.

<table>
<thead>
<tr>
<th>Correct</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Based on the arrangement of the molecules – can be a solid, liquid or gas.</td>
<td>Phase</td>
</tr>
<tr>
<td>How much of that substance is exposed. A powder has more of this than a block of it.</td>
<td>Surface Area</td>
</tr>
<tr>
<td>How much of a substance is available in solution. A weak solution is considered dilute.</td>
<td>Concentration</td>
</tr>
<tr>
<td>A chemical that is used to speed up a chemical reaction. This substance is not used up during the chemical reaction.</td>
<td>Catalyst</td>
</tr>
</tbody>
</table>
1.9 Collision Theory

Notes:

The collision theory explains why temperature has an effect on chemical reactions. Remember, as temperature increases the amount of heat energy also increases. This causes particles to move around faster. This increases the chance of an atom or a molecule bouncing into another one. In order for a reaction to occur particles must come in contact with each other. The faster they are moving the more chances they have to react.

In addition to the atoms becoming more likely to have collisions at higher temperatures, molecules that collide must have enough energy in order for a reaction to occur. If two molecules do not have enough energy, the two molecules will just bounce off one another without reacting. A high enough temperature is necessary to provide the kinetic energy or movement necessary to start a chemical reaction. We call the minimum amount of energy needed to begin a reaction the “Activation Energy”.
Notes:

Now we know that more energy in a system will cause more atomic collisions.

Let’s imagine that you are in a large group of students and are hanging around talking after lunch at school. You are all in the gym and it is pretty crowded. Every once and a while a few of the people bump into each other, but most people are able to move around without bumping into each other. What would happen if you added more energy to the system—just like heat adds energy to a chemical reaction? Let’s say someone tossed in a basketball and a game started right there on the court. What would happen?

Because the people are now using more energy, they run around faster and faster. Of course, there are many more collisions. In addition to the amount of collisions, because the people are running faster, the collisions are much harder and more intense. If you weren’t playing you would want to get out of the way! The same thing happens in chemical reactions described by the collision theory.
1.11 Practice 3

Notes:

Read the choices below, then select ALL choices that are true.

Feedback when correct:

Great! You knew that all of the choices accurately describe how temperature affects the amount of molecular collisions.

Feedback when incorrect:

Good attempt! All of the choices are correct. Higher temperature causes more collisions and provides more activation energy while at lower temperatures less collisions occur and prevent the particles from reacting with one another.

<table>
<thead>
<tr>
<th>Correct</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Higher temperature will cause more collisions.</td>
</tr>
<tr>
<td>Yes</td>
<td>Lower temperature will cause less collisions.</td>
</tr>
<tr>
<td>Yes</td>
<td>Higher temperature provides more activation energy.</td>
</tr>
<tr>
<td>Yes</td>
<td>Lower temperatures cause some atoms to bounce off each other and not react.</td>
</tr>
</tbody>
</table>
1.12 Temperature and Kinetic Energy

Notes:

Temperature relates to the average kinetic energy in the particles. Atoms and molecules with high temperatures have high kinetic energy and thus the particles move faster. On the other hand, lower temperatures mean that the particles within a substance move more slowly.

In this diagram, you can see the relationship between temperature and particle movement in solids, liquids, and gases. If you add heat to a solid, its temperature will rise as more energy is added to the system and the particles in the solid move faster. If enough heat is added to the system, the solid can change phase to a liquid. If we continue to add energy to the system, the particles in the substance will move even faster. If enough heat is added, the substance can change phase to a gas. Particles in a gas are moving rapidly and have more collisions with other particles in the substance.

Removing heat has just the opposite effect on particles in a substance. As the temperature of a material is lowered, the particles slow down and are less likely to collide.
1.13 Temperature and Kinetic Energy - Slider

**Notes:**

In addition to changing states of matter, temperature plays a role in chemical reactions, from the activation energy needed to begin the reaction as well as the reaction time. As particles move faster due to the increase in temperature, the more collisions these particles can have with other particles in order to react. As the temperature rises, molecules move faster and collide more vigorously, greatly increasing the likelihood of bonds being created or broken during the collision.

Here is a thermometer. Use the slider to see how particles pick up speed and have more collisions as the temperature is increased. If you cool the temperature down, you will see the particles move more slowly and have fewer collisions.
Choose the statement that best describes the effect of temperature on atoms and molecules.

**Feedback when correct:**

Excellent! You were able to identify that increasing temperature would lead to particles moving faster and having more collisions.

**Feedback when incorrect:**

You made a good attempt. Remember, as temperature is increased then the particle speed also increases. The amount of collisions also increases as the particles increase their speed.

<table>
<thead>
<tr>
<th>Correct</th>
<th>Choice</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>A temperature decrease results in particles having more collisions with other particles.</td>
</tr>
<tr>
<td>No</td>
<td>Decreasing temperature can cause a liquid to become a gas.</td>
</tr>
<tr>
<td>Yes</td>
<td>Increases in temperature cause particles to speed up and have more collisions.</td>
</tr>
<tr>
<td>No</td>
<td>Solids have more kinetic energy than gases.</td>
</tr>
</tbody>
</table>
One of the roles that temperature plays in chemical reactions is the rate at which the reaction takes place. Collisions between molecules are essential to a chemical reaction.

If heat is added to the system, molecules move around in a more violent manner. Increasing temperature also increases the molecules velocity which means there is less time between the collision of molecules at higher temperature. So, as temperature is increased, the rate of the reaction is also increased.

Starting at room temperature, on average about every increase of 10 degrees Kelvin in temperature will result in the reaction rate doubling. This means that if you increased the temperature of a reaction by twenty degrees Kelvin, the reaction speed would quadruple. This is not an exact amount, but it is a good estimate. The actual amount could vary based on other factors. As you progress through chemistry in a few years you will learn to calculate the actual amounts!
1.16 Temperature and Reaction Rates - Examples

Notes:

Let’s look at some examples of how temperature affects reaction rates:

It should be clear that you can increase reaction rates by increasing temperature. Imagine if you were cooking food on the stove. Remember, cooking of food is a type of chemical reaction. If you put the burner on a low setting, it may take a while to cook the food in the pan. If you increase the temperature of the stovetop, more energy is put into the system. Not only will the food you are cooking heat up, but it will also cook faster.

You can also decrease reaction rates by removing heat and lowering the temperature. You have most likely done this around your house. This is why we keep food in the refrigerator. Putting food in the refrigerator reduces its temperature slowing down the chemical reaction from microorganisms that break down food and make it spoil. Imagine having a gallon of milk stored in the refrigerator and one stored outside in the heat. If we waited a few days and compared the condition of the two gallons of milk, we would see that the milk stored at a higher temperature spoiled more quickly.
Notes:

Let’s look at some data to see how temperature affects the rate of reaction. In this experiment, the researcher measured the time it took for a reaction to be completed. The researcher measured the time it took for all of the product to be converted to reactants. In this case, bubbles formed during the chemical reaction. The researcher knew that when the solution stopped producing bubbles that the reaction was complete. The researcher ran the experiment at four different temperatures ranging from twenty-five degrees Celsius to fifty-five degrees Celsius.

What do you observe as the temperature of the reaction was increased?

As you can see the time it took the reaction to finish decreased. Remember the reaction rate doubles about every ten degrees of temperature increase. This is due to the higher kinetic energy of the particles.
1.18 Practice 5

**Notes:**

Here is a chance for you to order the sequence of steps that occur when you add heat to a chemical reaction. Place these steps in a logical order keeping in mind how adding temperature affects the rate of reaction.

**Feedback when correct:**

Great! You were able to properly identify the sequence of events when temperature is increased in an experiment. Heat was added, temperature increased leading to more particle collisions. Finally, the reaction rate of the experiment was increased.

**Feedback when incorrect:**

Nice try. The correct sequence is shown here. We would start with the mixing of chemicals. Heat must be added before temperature can increase which leads to more collisions and an increase in reaction rate.

<table>
<thead>
<tr>
<th>Correct Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two chemicals are mixed together and slowly some bubbles appear.</td>
</tr>
<tr>
<td>Heat is added to the experiment with a Bunsen burner.</td>
</tr>
<tr>
<td>Temperature increases due to the higher kinetic energy of particles.</td>
</tr>
<tr>
<td>More collisions of particles occurs due to the increased kinetic energy.</td>
</tr>
</tbody>
</table>
Correct Order

The reaction rate of the experiment is recorded and found to have occurred at a faster rate than it did without the addition of heat.
1.19 Final Practice

**Notes:**

For your final practice, please explain in your own words why temperature is so effective at speeding up chemical reactions. Use what you have learned in this tutorial to support your explanation. Try to give at least one example in your writing.

**Feedback:**

Thank you! Compare your response with the sample answer provided here.

Increasing the temperature increases the rate of reaction in a chemical reaction because the substance has more kinetic energy. The greater the energy the greater the temperature. This causes the particles to move faster and increase the chance of collisions. The more collisions the more reactions. If you were going to cook a grilled cheese sandwich on the stove, you would cook it faster if you added more heat. The opposite is true. If you want to slow down a reaction such as meat spoiling- you put it in the refrigerator to cool it down.
1.20 Lesson Review

Notes:

In this tutorial, you learned that temperature is a measure of heat and the kinetic energy of particles in a substance. As temperature increases, the molecules in a substance move around faster, have higher energy, and have more collisions with one another. Temperature increase usually leads to an increase in the reaction rate.
1.21 Thank You

Notes:

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