Connected Chemistry

Thermodynamics Unit

Lesson 8: Gibb's Free Energy

Student's Lesson at a Glance

Lesson Summary

Students are introduced to the concept of Gibbs free energy through the continuation of the shattered water glass example from Lesson 2. Students explore the three ways that reactions can progress and how the mathematical calculation of enthalpy and entropy allow a chemist to determine the free energy available. In the final activity, students explore the difference between a spontaneous and non-spontaneous reaction. The connection between free energy and spontaneity is established by students determining the change in free energy for the reactions in Lesson 5 - Activity 2-3. Students test their knowledge gained from the Gibbs activities using an analogy of a ball on a hill.

SWBAT (Students Will Be Able To)

- Define what free energy is and how to calculate it
- Identify how Gibbs free energy and the spontaneity of a reaction are related

Essential Vocabulary

Keep a list of all important words from this lesson. This list, in addition to the lists from other lessons, will make studying easier and improve scientific communication skills. The essential vocabulary from the unit is in bold. Additional words that will expand your scientific vocabulary are in italics.

CCC Reminder

- Students and teachers from many different schools helped designed CCC so that the lessons are more helpful and meaningful for all classroom participants.
- Many questions will ask you "what you think" or "to make predictions." The only answer that is wrong is the answer that is left blank.
- Recall that entropy in a system is always increasing.
- Chemistry and physics are closely related. Researchers from both fields view "work" as a measured value resulting from some form of energy transfer. Work comes in two categories: non-mechanical work and mechanical work. In this lesson you will be introduced to the concept of non-mechanical work. Examples of non-mechanical work include chemical work and electrical work.

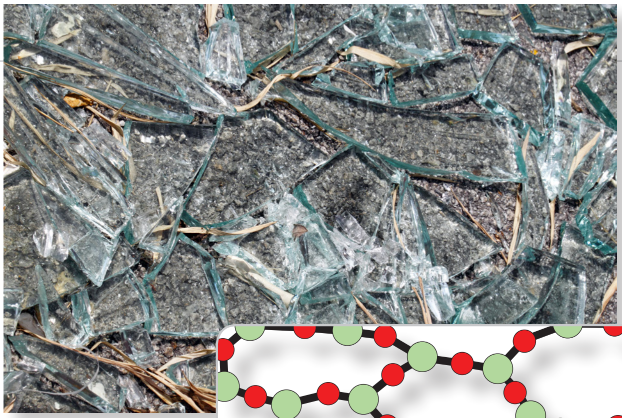
- Use the vocabulary section and note section to take good notes so that studying for tests and quizzes is easier.
- Supporting claims with evidence is not only a skill that scientists use, but a skill that will help you in other classes and everyday life.
- Draw a key when you are sketching. Symbolic keys can help you and others decode your sketches at a later time.
- There is a periodic table and list of common elements used in the back of this book. You will need to refer to the periodic table often.

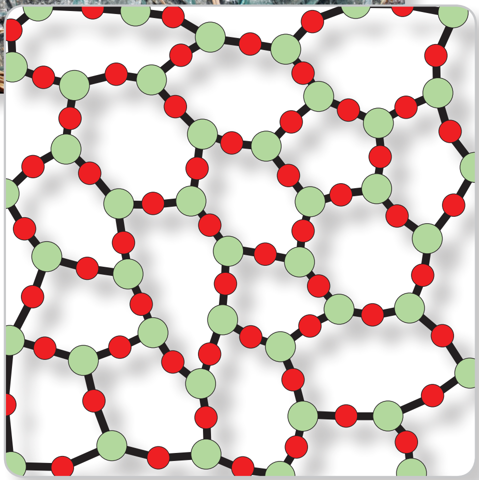
Notes

Homework

Upcoming Quizzes/Tests

Activity 1: Connecting





Consider the following statement: a piece of shattered glass can never reform into the original glass. Some people may disagree with this statement because with enough time, superglue, and human effort, the glass might be reassembled. The problem is that the person putting the glass together is also contributing to a change in entropy. We increase entropy through the use of energy from the food we eat. Our bodies reduce entropy by taking the energy from food and building new ordered sets of cells. Over time, the total change in entropy of the body always increases and never decreases. If glass and human beings are regarded as a whole system, a small reduction in disorder - such as the reassembly of glass and the development of new human cells - is not enough to change the overall total disorder of the system.

1. Regarding entropy, how is burning a piece of paper similar to shattering a glass?

Glass is made from different types of molecules that are fused together at high temperatures into a solid. Most solids have orderly atomic arrangement, but glass has a random pattern. When glass shatters, energy is absorbed as the intermolecular bonds break between the glass molecules. This means that the enthalpy of the glass has also changed. The glass has moved from a higher state of enthalpy (whole piece of glass) to a lower state of enthalpy (shattered glass).

2. How are burning paper and glass breaking dissimilar?

By combining the values of enthalpy and entropy, we can determine if a reaction will *spontaneously* move forward from reactants to products. Spontaneous reactions move forward without any energy input from its surroundings. Scientists have discovered that reactions which reduce enthalpy while increasing entropy spontaneously move forward. On the other hand, reactions which increase enthalpy while reducing entropy not spontaneously move forward. In 1875, a scientist named Josiah Gibbs proposed a theory to balance these two important concepts of thermodynamics. **Gibbs free energy** is defined as the capacity of a system to do non-mechanical work. In most reactions, this work occurs in the form of heat. "***G***", the symbol that represents Gibbs free energy, is the measure of the non-mechanical work done on a system. Gibbs' theory is represented by the following equation

$$\Delta G = \Delta H - T\Delta S$$

3. Do you think that free energy can be directly measured, such as the value of temperature? *Support your claim with evidence.*

Activity 2: Determining Spontaneity of Reactions

Reactions can be classified as spontaneous or non-spontaneous. A **spontaneous** process releases free energy. A **non-spontaneous** process only happens when outside action on the system introduces energy to drive the process. For instance, emergency ice packs used to treat sports injuries involve a non-spontaneous reaction that takes energy from the surroundings in order to generate the cold-feeling pack. A non-spontaneous process absorbs free energy. When ΔG is negative, a process or chemical reaction proceeds spontaneously in the forward direction. When ΔG is positive, the process proceeds spontaneously in reverse.

In Lesson 5, Activity 2-3 you collected data from three reactions. For each reaction calculate the ΔG using the data. Show work in the space provided. Using your calculations, determine if the process is spontaneous or non-spontaneous based on the value of ΔG. Circle one word from each pair of terms. Recall that ΔG is calculated with the following equation:

$$\Delta G = \Delta H - T\Delta S$$

4. Calculate ΔG for using data collected from the teacher demonstration in Lesson 7 on page 69. *Show your work in the space below.*

5. The reaction in the teacher's demonstration is **spontaneous** or **non-spontaneous**.

6. Calculate ΔG for using data collected from Lesson 7, Activity 3, Reaction 1 on page 72. *Show your work in the space below.*

7. Reaction 1 is **spontaneous** or **non-spontaneous**

8. A spontaneous reaction would **increase** or **decrease** entropy. *Support your answer with evidence.*

9. If ΔG for a given reaction is equal to zero, what do you think would happen when the two reactants combine?

10. A rusting nail is an example of a **spontaneous** or **non-spontaneous** reaction. *Support your answer with evidence.*

11. When combining ammonium nitrate and water in a beaker, the beaker feels cold to the touch. The dissociation taking place in the beaker is an example of a **spontaneous** or **non-spontaneous** process. *Support your answer with evidence.*

12. When making inexpensive jewelry, zinc is often coated with silver or gold through a process called electroplating. Zinc metal is placed in an aqueous solution of silver or gold. An electrical current must be passed through the solution for the redox reaction to occur. The reaction that is taking place is an example of an **spontaneous** or **non-spontaneous** reaction. *Support your answer with evidence.*

Lesson Reflection Questions

13. If a reaction has reached equilibrium, what will the ΔG be for the reaction? Explain your answer.

14. If a reaction is spontaneous, does that mean that the reaction will occur quickly? Provide evidence for your answer.