A web-based applet to teach Le Chatelier's principle
Un programa en la Internet para enseñar el principio de Le Chatelier

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Abstract

Chemical educators agree that the concept of chemical equilibrium in introductory chemistry is difficult for students to learn. Considerable research has been conducted aimed at identifying common misconceptions that students have about the topic. Because of its complexity, many chemistry professors end up teaching students how to perform a few specific calculations, but avoid actually teaching students the physical meaning of the concept. Students may not even learn the physical meaning of terms that are commonly used when discussing chemical equilibrium. Other difficult topics in science are being taught effectively through the use of computer simulations and animations. However, to date, the authors were unable to find simulations that they found effective for teaching the concept of chemical equilibrium. Consequently, two applets were designed and written by the authors to meet their educational objectives. The first applet deals with the concept of chemical equilibrium, and was previously published. The second applet, which is described in this current article, deals with chemical equilibrium applied to Le Chatelier's principle. Both applets can be used on the Internet free of charge. The text for both applets is written in Spanish and in English.

Key words: *Le Chatelier, equilibrium, teaching/learning aids, computer-based instruction.*

Resumen

Los maestros que enseñan la química están de acuerdo en que el concepto de equilibrio químico es difícil de aprender para estudiantes de química básica. Bastante investigación se ha hecho con el propósito de identificar concepciones alternativas que tengan los estudiantes acerca del tema. Debido a la complejidad del tema, muchos profesores de química enseñan cómo hacer algunos cálculos básicos, pero no enseñan el significado físico real del concepto. Puede ser que los estudiantes ni siquiera aprendan el significado físico de los términos que se utilizan para hablar del tema. En otras áreas de la ciencia, se ha tenido éxito utilizando animaciones y simulaciones de computadora para enseñar temas difíciles. Pero los autores no encontraron un programa que fuera efectivo para la enseñanza del tema de equilibrio químico. Por lo tanto, dos programas fueron diseñados y escritos por los autores para lograr sus objetivos educacionales. El primer programa trata el concepto de equilibrio químico y fue publicado anteriormente. El segundo programa trata el concepto del Principio de Le Chatelier, y está descrito en el presente artículo. Ambos programas están disponibles gratis en la Internet. El texto para ambos programas está escrito en español e inglés.

Palabras clave: *Le Chatelier, equilibrio, ayudas de enseñanza/aprendizaje, instrucción basada en computadoras.*

INTRODUCTION

Educators who teach introductory chemistry courses generally agree that it is difficult to teach the concept of chemical equilibrium. It is often cited that students have difficultly visualizing what occurs when a chemical reaction reaches equilibrium. (BERQUIST, 1990; HUDDLE, 2000; PEÑA 1999; RAVIOLO, 2001; TYSON, 1999) Some science educators who were faced with the problem of helping students visualize abstract concepts have started to use computer animations and simulations. Consequently, the authors began to search for existing simulations that deal with the concept of chemical equilibrium. Several sites that post educational applets (little programs) were searched, including one site that has many useful applets: www.merlot.org. However, after examining the options, they decided to design and write their own applets.

The first applet that the authors wrote deals with basic principles of chemical equilibrium. (SANDBERG, 2003) This applet can be downloaded for free from the site indicated in the reference. It can also be viewed, and utilized at info.nwmissouri.edu/~bellamy/

The second applet that the authors made is described in this article and is extension of the first applet. This current applet covers the basic principles of Le Chatelier's Principle. While reading this article, it may be useful to the reader to view the Le Chatelier's Principle applet at info.nwmissouri.edu/~bellamy/. Please note that this site sometimes undergoes maintenance on Friday afternoons.

In the next section of this article, the different exercises that accompany the applet are discussed. The educational objectives of the exercises are also discussed. It should be noted that professors who are interested in using the applet can use the exercises that are provided. They can, of course, also write their own exercises to accompany the applet. These exercises could simply be given to students as a handout.

METHODOLOGY

It may be beneficial for the reader to start by briefly viewing the first applet developed by the authors, the Chemical Equilibrium applet (see SANDBERG, 2003). Upon viewing the applet it is evident that that students can add any combination of N_2, H_2 and NH_3 gases and see the equilibrium concentration of each gas after equilibrium has formed. Students can also see the effects of changing the temperature of the system.

In contrast to the Equilibrium applet, the Le Chatelier's principle applet starts out at equilibrium. Students can apply a stress that causes the equilibrium to shift. The stresses that can be applied are changing the volume of the container, changing the temperature, adding an inert gas, and changing the concentration of either products or reactants. To help students quantify the change in the system, an equilibrium table displays the concentration of each gas before and after the stress was applied. The table also gives the equilibrium concentration of each gas after each stress is applied. Again, the Le Chatelier's principle applet can be viewed at info.nwmissouri.edu/~bellamy.

The authors use the Le Chatelier's principle applet in two different ways. The first is to project the applet on a screen in the classroom as the topic is introduced. Students are asked to predict changes in the equilibrium before stresses are applied to the system. After the students make their predictions, the result of the perturbation is calculated by the applet, and the students can see the result on the screen. When students make incorrect predictions, the class is asked to discuss why the predictions are not correct. In this way, incorrect ideas that students have about chemical equilibrium are confronted.

After the topic has been introduced in class, each student is given a hard copy of exercises to work on their own. They perform the excises from any computer that has Internet access. The same problems that are given to the students can be found in the "Concepts and Problems" section of the applet. As the students work the problems in the "Concepts and Problems" section, they are given immediate feedback. That is, the program tells them if their answers are correct. In some cases, prompts are given when incorrect responses are chosen. The purpose of giving the students a hard copy of the exercises is to ensure that they will have material to review when studying for exams. After students perform the exercises on their own, the concepts are reviewed as a class.

The types of exercises that are addressed by the applet are given below. Please note that not all of the different aspects of Le Chatelier's principle are covered. This applet is not meant to be all-inclusive. It is meant to address some specific educational objectives. Any instructor who chooses to utilize the applet in their course will need to decide how to address the aspects of Le Chatelier's principle that the applet omits.

The details about how the software accomplishes the computations in the applet are covered in the manuscript that accompanies the first applet. (SANDBERG, 2003).

Exercise – Verifying that the system is at equilibrium before any stresses are applied

Students are asked to ensure that the system is initially at equilibrium. This requires them to calculate the reaction quotient, Q, and compare it with the value of the equilibrium constant. The equilibrium constant that is used is K_c, so students work with molar concentrations.

Educational objective

Students have likely already been taught how to calculate Q. It is also likely that they were taught how to use the value of Q to predict the direction in which the equilibrium will shift. The purpose of this exercise is to refresh their memories, and to reinforce the idea that when Q = K, the system contains equilibrium concentrations.

Exercise – Shifting an equilibrium

Students are asked to add or remove some reactant (N_2 and H_2) or product (NH_3). They are asked to predict how the concentrations of the two reactants and the product will change when the system is perturbed. When they press the equilibrate button they see a visual representation of the concentrations of each molecule before and after the perturbation.

Educational objective

The goal of this exercise is to help students form a visual image of what it means for a reaction to "shift left" or "shift right." After performing this exercise, students hopefully understand that when a reaction shifts left, product molecules are converted into reactant molecules until the reaction quotient, Q, again equals the equilibrium constant, K_c. A limitation of this exercise is that it does not deal with kinetics.

Exercise – Compressing an equilibrium mixture of gases

The volume of the reaction chamber can be changed with the mouse. When the volume is changed, students see that the same quantity of each gas is contained in a smaller volume. This means that the concentration of each gas increases.

Students are then asked to calculate the reaction quotient, Q, and compare it with the value of the equilibrium constant at the temperature of the equilibrium. At this point, many of the students can predict which direction the reaction will shift.

Educational objective

After reading a general chemistry textbook, many students know that changing the volume (or pressure) of an equilibrium mixture of gases causes the equilibrium to shift towards the side of the equilibrium that contains fewer moles of gas. Often, however, they have no idea why this is true. This exercise will hopefully help the students see that changing the volume (or pressure) simply changes the concentrations of products and reactants in the equilibrium.

One limitation of this exercises it that all of the substances involved in the equilibrium are gases. Consequently, students do not learn that changing the volume of the vessel does not significantly change the concentration of products and reactants that are not gases. Also, the applet contains only one equilibrium. This equilibrium has fewer moles of gas on the left-hand side of the reaction. It should be stressed to students that the effect of changing the volume of the vessel would be reversed for an equilibrium that has fewer moles of gas on the right-hand side of the reaction.

Exercise – Adding an Inert Gas

Students are asked to go to a link within the applet. They are told that in this exercise that they can add an inert gas to the equilibrium mixture. They are also told that in this link the molecules in this exercise are scaled to their actual size. This is an attempt at humor. Molecules scaled to their actual size, of course, cannot be viewed. Consequently, students see a reaction vessel that appears to be empty.

Educational objective

Students see that the molecules of gas are very small compared to the size of the container. Thus, adding an inert gas does not significantly change the volume that N_2, H_2, and NH_3 occupy. Consequently, the concentrations of these gases do not significantly change when an inert gas is added. When they calculate the value of the reaction quotient, it is of course, still equal to K_c since the concentrations of the reactants and the product did not change.

Exercise – Changing the temperature of the equilibrium mixture of gases

Students are asked to change the temperature of the equilibrium mixture. They are asked if the concentrations of the gases changed when they changed the temperature. They are then asked to calculate the value of the reaction quotient, and predict the direction of the shift of the equilibrium.

Educational objective

Students can see that changing the temperature does not change the concentrations of the gases. Consequently, they realize that the value of the reaction quotient will not have changed. However, they can also see in the applet that, as the temperature changes, the value of the equilibrium constant changes. Thus, upon changing the temperature of the reaction mixture, the value of Q no longer equals the value of K_c, and the equilibrium will shift. The goal is for students to see that changing the temperature of the mixture is a different type of perturbation than those that cause the reaction to shift due to changes in the concentrations of the reactants and products.

Brief mention is made of the relationship between the change in enthalpy, DH, of the reaction and the direction of the shift in the equilibrium. However, the topic can, of course, be covered in much greater depth if the instructor so chooses.

Results and discussion

The Equilibrium Applet has been used for two years at Northwest Missouri State University. The Le Chatelier's principle applet is currently being used for the first time at the same institution.

The Le Chatelier's applet seems to meet the educational objectives listed earlier in this article for most students. It would be interesting to quantify the results of using the applets. To do this the authors considered using the results of pre and posttests to quantify the results of using the two related applets. However, a literature search revealed that experts in the field believe that these results may not be valid when applied to applets. (Kim, 2000)

Consequently, the same approach that was taken with the Equilibrium Applet is being used with the Le Chatelier's principle applet. That is, the learning objectives are being made known to the students who use the applet, as-well-as to other professors who use them.

As students and peers provide feedback about the ability of the applets to accomplish the learning objectives, the applets are modified.

CONCLUSIONS

The Le Chatelier's principle applet is being tested on traditional college students at Northwest Missouri State University. The applet is also being test on students of the Missouri Academy of Math Science and Computing who attend NWMSU. The academy students are gifted high school juniors and seniors.

In a very qualitative sense, both traditional, as well as gifted students have found the applet to be useful. No students have complained about having to do the exercises that accompany the applet.

The authors believe that the future of animations in science education is very bright. Complex topics can be visualized in ways that were previously not possible. Well-designed applets can effectively confront misconceptions. However, care must be taken to ensure that the same applets do not create other misconceptions.

The Le Chatelier's principle applet will hopefully prove to be useful to some chemical educators. It will also hopefully provide ideas to other professors who will write applets for other topics, or applets that are similar to this one, but improved.

Finally, it is hoped that those who make educational software will see that little extra effort is required to make the software bilingual, making the software available to a much wider audience.

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