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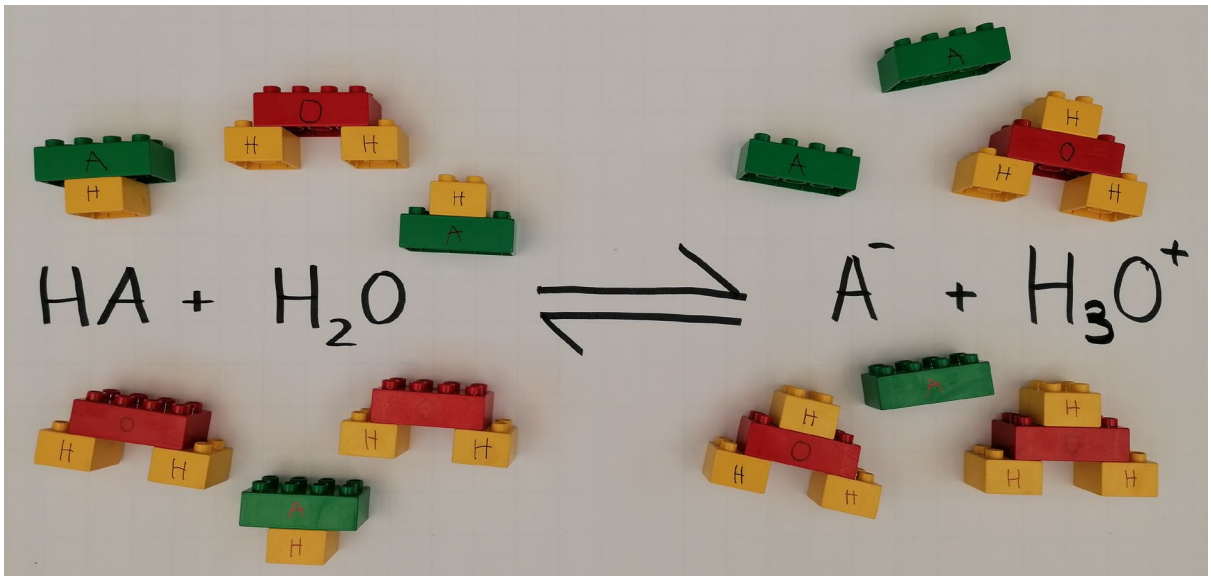
Extension Activity 1: The function of buffers

Much ado about nothing: spot misleading science claims and explore rapid antigen tests and buffers

Activity 3 reveals that the buffer stabilizes the pH of a solution. The following activity shows what happens at the particle level using a hands-on model. Initially, a brief revision of the concept of acids and bases can be given, if needed. Following a short explanation of the general reaction equation for a buffer system, the students use the model to understand what happens to the chemical equilibrium after adding an acid.



Model of buffer function

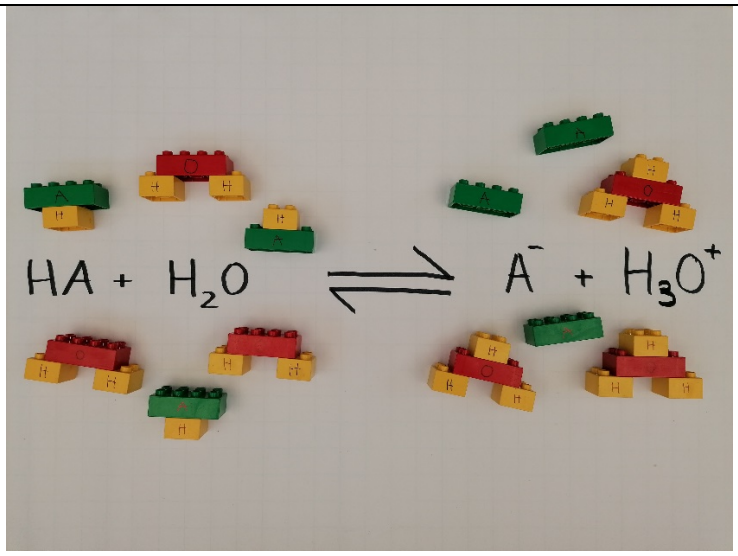
Image courtesy of the author

Materials

- Labelled bricks of Lego/Duplo
- Chalk or removable marker pen

Procedure

1. Baseline



General reaction equation of buffer systems; yellow: hydrogen; red: oxygen; green: anion
Image courtesy of the authors

Scientific background

A buffer system consists of a weak acid and its conjugate base within the same solution. The ongoing reactions in buffer systems are thus proton-transfer reactions. The conversion of a weak acid to its anion and back are in dynamic balance.

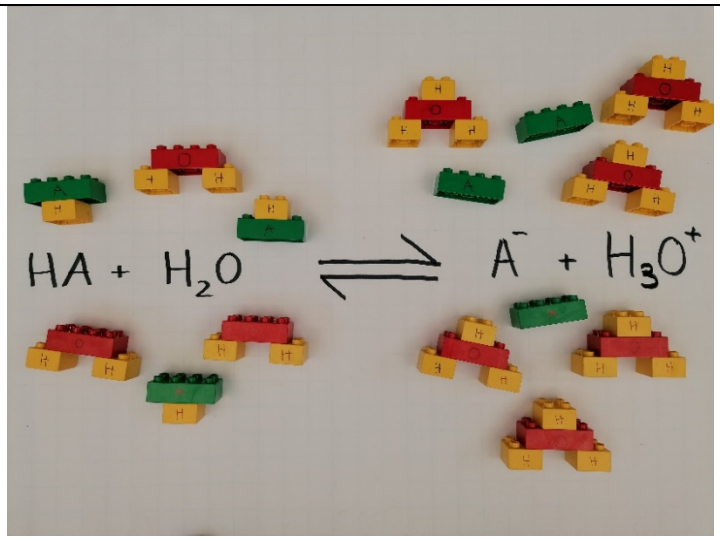
The model simplifies the content by reducing the number of particles, illustrating the acid molecules as single particles, and using colours.

Activity

Teacher activates prior knowledge of the definition of pH as a measure of the concentration of hydronium ions (H_3O^+) and the reactions of acids and bases.

Students name the different particles. They understand the forward and back reaction by de- and reconstructing the DUPLO particles.

2. Acid added



Situation with added acid
Image courtesy of the authors

Scientific background

Since the pH level depends on the overall concentration of hydronium ions, adding these should decrease the pH level.

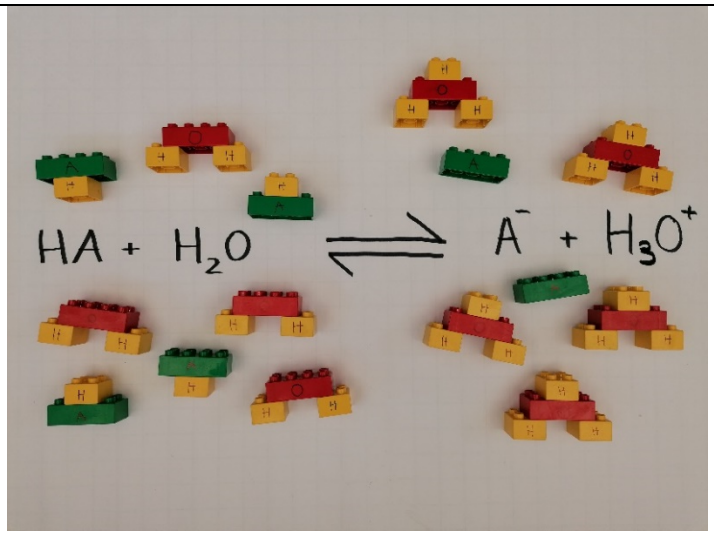
Accordingly, by adding more acidic solution (H_3O^+), the equilibrium is destroyed. Through this, the back reaction, producing water (H_2O) and acid molecules (HA), is favoured, thus stabilizing the system. This means that most of the added hydronium ions (H_3O^+) react with anions (A^-), forming water and acid (HA).

Activity

The teacher adds more hydronium ion particles to the right side of the reaction. They ask the students which proton transfer will now take place.

The students can test their hypotheses by picking the blocks apart and sticking them together to reform the particles.

3. A new equilibrium



New equilibrium is accomplished after dividing one hydronium ion
Image courtesy of the authors

Scientific background

As a result, the overall concentration of hydronium ions does not increase as much as expected, and the pH level barely decreases.

Activity

The teacher can interrupt the exercise after the students have disassembled one hydronium ion because any more reaction steps would lead to an unbalanced system.

Explanation

A buffer is a solution that guarantees a stable pH level, although an acid or base is added. The buffer can be generated by mixing a weak acid with its conjugate base. The general chemical reaction of buffers is shown by the following equation:

$$HA + H_2O \rightleftharpoons A^- + H_3O^+$$

HA: protonated acid A^-: anion of the acid H_3O^+: hydronium ion

When adding an acidic solution to the buffer solution, the hydronium ions react, forming water. The resulting pH level is thus stabilized by the existing dynamic equilibrium. An example of a buffer solution is the phosphate buffer used in this experiment. It can be produced by mixing solutions of sodium dihydrogen phosphate (NaH_2PO_4) and disodium hydrogen phosphate (Na_2HPO_4) (or bought premixed).