PAL Worksheet – Chem 6A

Buffers

I. Identifying the components of a buffer

A buffer consists of approximately equal amounts of a weak acid and its conjugate base, usually with a millimolar (mM) concentration.

1. Draw the dissociation reactions for the following acids. Indicate for each acid whether it is a weak acid (partially dissociates) or a strong acid (dissociates completely). For each reaction, circle the conjugate base.

   A. HNO_3

   B. HCN

   C. CH_3COOH

   D. H_2CO_3

2. Write the weak acid and conjugate base of each of the following. The weak acid formula is given.

   Example: HCN/CN^-

   A. HNO_2

B. HBr

C. H_3PO_4

D. $H_2PO_4^-$

II. How buffers work.

Many biochemical processes occur in a very narrow pH range. For example, the normal blood pH range of human beings is 7.35-7.45. Deviations outside of this range can be dangerous or even fatal. A person with a blood pH of 7.1 would be unconscious and probably die if the acidic pH of the blood was not quickly treated. Buffers are very important in living organisms because they resist changes in pH. How they accomplish this is by reacting with added acid or base. We will use a generic weak acid, HA, to show how this works. The conjugate base of HA is A^-. These two species are in equilbrium with each other:

$$HA \rightleftharpoons H^+ + A^-$$

The buffer HA/A- resists changes in pH as follows:

Added acid:

$$A^- + H^+ \text{ (added acid)} \rightarrow HA$$

Added base:

$$HA + OH^- \text{ (added base)} \rightarrow A^- + H_2O$$

When a buffer is present, the added acid or base is essentially absorbed by the buffer because the buffer reacts with it chemically as shown above.

1. For each of the following buffers, draw a reaction showing how the buffer reacts with added acid and with added base. The weak acid formula is given.

A. HNO_2

B. H_2CO_3

C. HCO_3^-

D. $H_2PO_4^-$

2. A. Draw two beakers, one containing water and one containing H_2CO_3/HCO_3^-. Then draw what happens in each beaker if HCl is added.

B. Draw two beakers again, one containing water and one containing H_2CO_3/HCO_3^-. Then draw what happens in each beaker if NaOH is added.

3. Write a description of what you drew in # 2 and explain how this illustrates how a buffer works.

III. The blood buffer system. (Note: not all lecture sections will do this part).

The blood buffer system includes H_2CO_3, HCO_3^-, and CO_2. While CO_2 is not itself an acid or base, it is part of the system due to the decomposition of H_2CO_3 to CO_2 and H_2O.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$$

Blood pH, represented by H+ in the above equation, is tied to respiration, represented by CO_2. If pH or any other component of this system changes, there will be an adjustment in the equilibrium among the species in the reaction above, according to LeChatelier's principle.

1. For each of the following, predict what will happen to the rates of the forward reactions.

A. decrease in CO_2 concentration

B. increase in pH concentration

C. increase in H+ concentration

D. increase in water concentration

2. Kussmaul respirations illustrate the connection between the blood buffer system and respiration. It occurs in diabetes (especially in Type 1 diabetes) when the blood becomes acidic.

A. What happens to breathing during Kussmaul respirations?

B. How does this physiological response alleviate the condition of acidosis?

3. In chronic obstructive pulmonary disease (COPD), patients have difficulty exhaling.

A. How might difficulty in exhaling affect the CO_2 concentration in the blood?

B. How might difficulty in exhaling affect blood pH?

4. Which of the following could be used to treat acidosis in the blood? **Explain.**

A. HNO_3 B. HCO_3^- C. H_2CO_3 D. NaOH