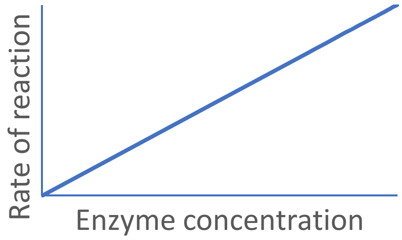
TB5 –Rate of Enzyme Reactions

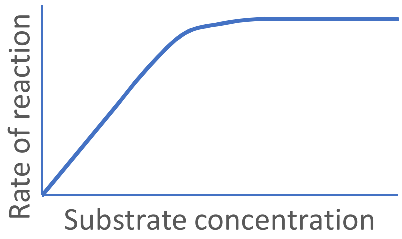
Enzymes catalyse many different chemical reactions. In any chemical reaction, it is important to know the effect that changing the **reaction conditions** will have. For example, what is the **optimum temperature/pressure/pH**? etc. Reactions which are catalysed by enzymes are exactly the same, and the conditions of a reaction must be considered.

ENZYME CONCENTRATION



The **concentration** of the enzyme present is critical in a reaction. Enzymes work by accepting a **substrate** into their **active site**, then catalysing the desired reaction, and releasing the products. If there are many substrates, and very few enzymes in the mix, then it will take a long time for all the substrate to react. Each enzyme takes a different amount of time to catalyse a reaction. Some can catalyse up to one million per second, some are relatively much slower. Ultimately, the more enzymes you have, the faster the substrates can react.

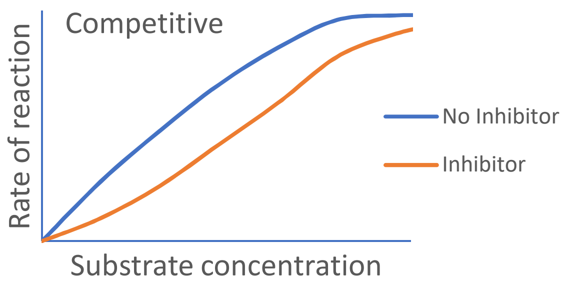
SUBSTRATE CONCENTRATION



Similarly, a reaction can only occur if there is enough of the substrate there too. If there are many more enzymes than substrates, then increasing the amount of substrate in the mix will increase the rate of reaction. This will continue until the enzymes reach their **saturation point**. This is the point where every enzyme is working at its **maximum capacity**. At this point, adding more substrate doesn't change the rate of reaction, because the concentration of enzymes has become the **limiting factor**.

INHIBITOR CONCENTRATION

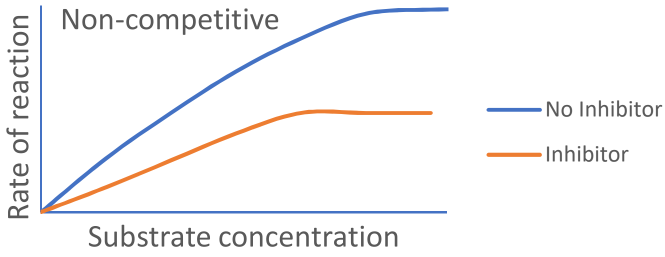
There are two different types of **inhibitors**: **competitive**, and **non-competitive**:



Competitive inhibitors have a similar shape as the substrate. This means that they will competitively bind to the enzyme's active site. The higher the concentration of a competitive inhibitor, the lower the rate of the desired reaction. But if you increase the concentration of the substrate, then statistically it will be more likely that a substrate enters any active site than a competitive inhibitor does. This means that you can increase the rate of reaction by increasing the concentration of the substrate when a competitive inhibitor is bound.

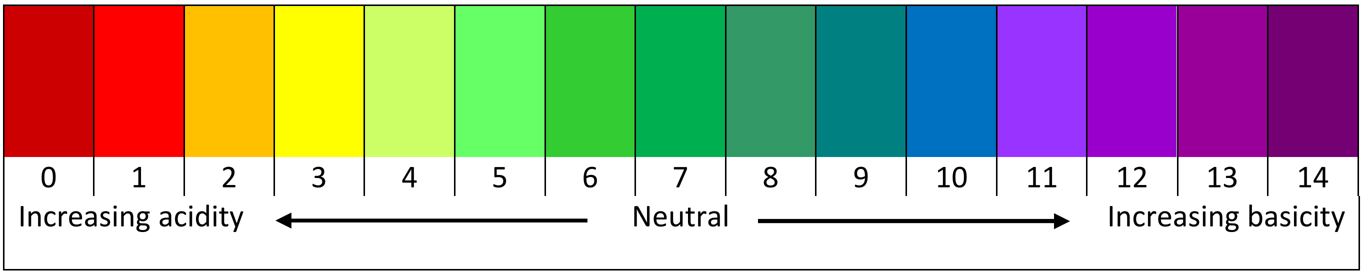
Produced by Adam Stubbs at Newcastle University as part of a summer outreach project.

Non-competitive inhibitor work differently. These aren’t shaped like the substrate, so cannot bind to the active site. Instead they bind elsewhere on the enzyme, in doing so, they trigger a **conformational change** to the structure of the enzyme. This indirectly changes the shape of the active site, so that the substrate is no longer **complementary** to the enzyme. Because they don’t compete with the substrate, increasing the substrate concentration won’t have as great an effect. Each non-competitive inhibitor effectively takes-out an enzyme, effectively reducing the concentration of the enzyme. Increasing the concentration of substrate will still increase the rate of reaction, but only up until the point where all of the available enzymes are working at their maximum capacity. At this point, the concentration of usable enzymes is the limiting factor.



THE EFFECT OF pH

The pH of a reaction system is incredibly important, especially for biological ones such as enzymes. pH is a measure of the concentration of **H^+ ions** present within a system. The more acidic a system is, the higher the concentration of H^+ ions. Systems which are neutral have an equal concentration of H^+ ions than OH^- ions. Aqueous systems which are basic have a higher concentration of OH^- ions than H^+ ions.



pH scale. The neutral point is only pH 7 at 25 °C, as pH is dependent on temperature.

By changing the pH, the concentration of H^+ and OH^- ions changes. These ions are highly reactive, and therefore can react with, and affect enzymes. There are two primary ways in which this occurs. Firstly, they can **denature** the enzyme. This occurs when the pH changes enough so that the bonds which hold the enzyme in its specific **tertiary structure** break down. This changes the shape of the active site, which becomes no longer complementary to the substrate. Therefore, the enzyme cannot work.

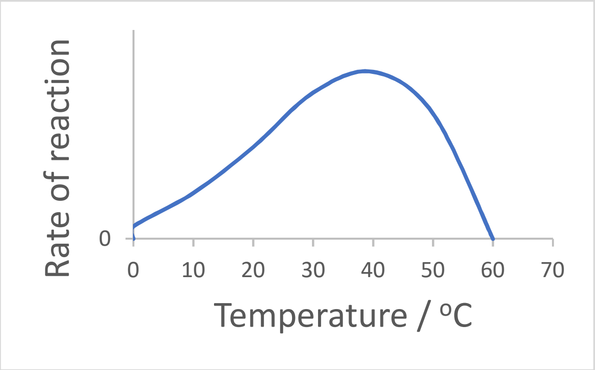
Secondly, the change in pH can affect the concentration of ions in the active site of the enzyme. Active sites are composed of amino acids. By changing the pH, the charges surrounding the active site will change, and this will stop the active site from efficiently binding to the substrate. Therefore, the substrate cannot bind and the enzyme cannot function.

Enzymes have a very narrow pH range. Amylase, which is secreted by the salivary glands has an optimum pH around 7. Whereas pepsin, which breaks down proteins, is found in the stomach, which contains stomach acid. Pepsin therefore works best at low pH levels, where it is very acidic.

TEMPERATURE

Temperature is a measure of the **average kinetic energy of molecules**. A higher temperature means that molecules are vibrating faster, and at low temperatures, the molecules vibrate slowly. At very low temperatures, substrates and enzymes have very little energy, and this means that they cannot react very fast. For a reaction to occur, an **enzyme-substrate complex** must have sufficient energy to overcome the **activation energy** for a reaction. As temperature increases, the enzyme-substrate complexes which form have more energy, and the chance that any one complex has enough energy to react increases. Therefore, increasing temperature increases rate of reaction.

However, if the temperature is increased too much, then the enzyme can denature. This happens because the extra kinetic energy which the enzyme has causes the enzyme to vibrate rapidly, and is enough energy to break some of the bonds which give the enzyme its specific tertiary structure. This is a process of denaturing. Now, as the temperature increases, the active site changes shape more, and the substrate cannot bind. Past a certain point, the temperature is so high that the enzyme has completely denatured and cannot bind to the substrate at all.



This means that there is an **optimum temperature** at which an enzyme works best. Many enzymes work best in the conditions that they are naturally in, so many work best around body temperature, ≈40 ^oC.