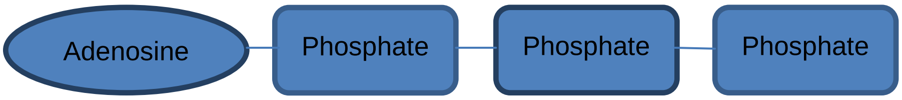
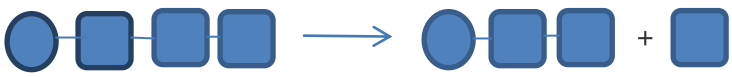
Powering our muscles

Carbohydrate is arguably the most important source of energy for athletes. No matter what sport you play, carbohydrates provide the energy that fuels muscle contractions. Both energy drinks and sports drinks are a good source of carbohydrate that is quickly absorbed into the body. Many energy drinks also contain caffeine which behaves in a totally different way.

The energy required for muscle contraction comes from a molecule called adenosine triphosphate (ATP).



In ATP, an organic (carbon-based) group called adenosine is attached to three phosphate groups. The phosphate groups are involved in the energy storage. The loss of one of the phosphate groups produces adenosine diphosphate (ADP) and gives out 30 kJ mol^{-1} of energy. It is an exothermic reaction. This reaction supplies the energy needed to make our muscles move.



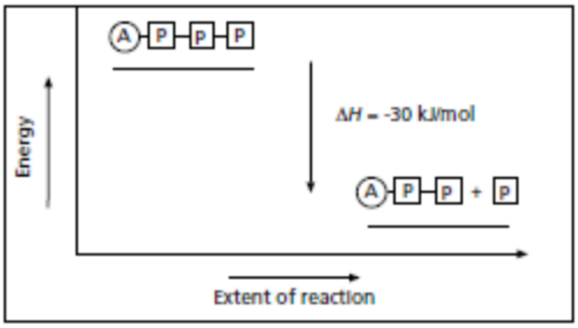
$\Delta H = -30$ kJ mol^{-1}

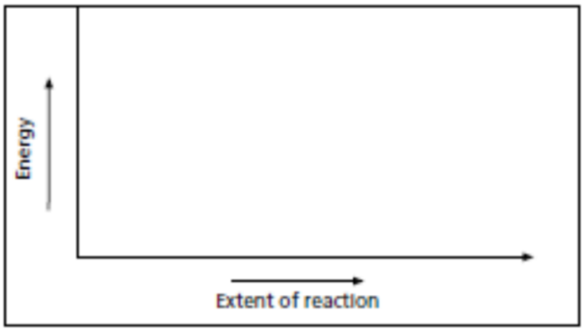
ATP → ADP + phosphate

At any one time, we only have a small amount of ATP in our muscles and so ATP must be regenerated in our bodies. In fact, the above reaction is reversible and ADP is reattached to a phosphate to make ATP. This requires an input energy of 30 kJ mol^{-1} ie it is an endothermic reaction. This energy comes from the breakdown of food molecules such as carbohydrates, fats and proteins. The primary source is carbohydrates such as glucose, $C_6H_{12}O_6$. In fact 180 g of glucose (1 mole) can release about 3000 kJ when reacted with oxygen. Our bodies release this energy gradually *via* the ATP/ADP cycle.

The energy level diagram for the formation of ADP from ATP is shown below.

1. Draw an energy level diagram for the regeneration of ATP from ADP and phosphate





Many sports drinks contain carbohydrates such as glucose which are quickly absorbed into the bloodstream. If the glucose is not needed straight away it is stored in the muscles and liver as a carbohydrate called glycogen, which consists of many glucose molecules joined together. Glycogen is the source of energy most often used for exercise. It is needed for any short, intense bouts of exercise from sprinting to weight lifting because it is immediately accessible. Glycogen also supplies energy during the first few minutes of any sport. During long, slow duration exercise, fat can help fuel activity, but glycogen is still needed to help breakdown the fat into something the muscle can use.

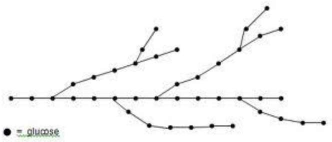


Figure A glycogen molecule.

Our bodies release the chemical energy stored in glucose through the process of respiration. There are two main types of respiration; aerobic and anaerobic.

During aerobic respiration, glucose reacts with oxygen to produce carbon dioxide and water.

Glucose + Oxygen → Carbon dioxide + Water $\Delta H = -3000\ kJ\ mol^{-1}$

2. Write the balanced symbol equation for the aerobic respiration of glucose.

Aerobic respiration is our main source of energy supply but it does rely on a continuous supply of oxygen being supplied through the bloodstream. Endurance athletes such as long distance runners, rely on aerobic energy production to maintain their ATP levels for long periods of time.

During anaerobic respiration no oxygen is involved and less energy is released. The glucose molecule splits into two molecules of lactic acid, which build up in the muscles during high-intensity exercise. Anaerobic respiration occurs when the bloodstream cannot supply oxygen fast enough for aerobic respiration. Anaerobic respiration can only occur for short periods of time. It is thought that the buildup of lactic acid may be a factor in fatigue.

Glucose → Lactic acid $\Delta H = -150\ kJ\ mol^{-1}$

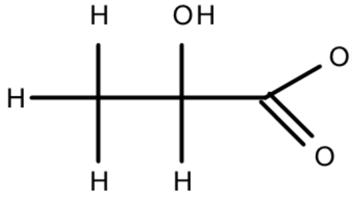


Figure Lactic acid.

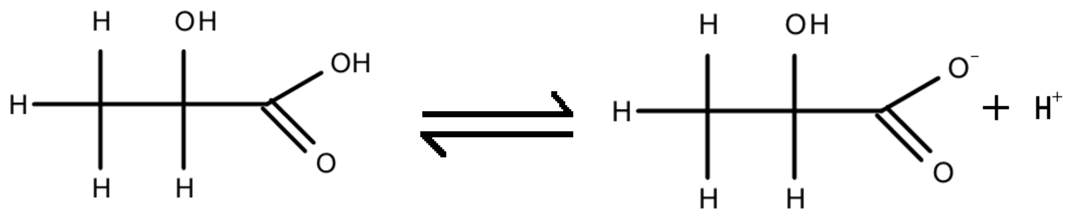


Figure Lactic acid to lactate ion + H^+.

Lactic acid is a weak acid. In the body it exists as both lactic acid and the lactate ion, because some of the particles dissociate (split) releasing an H^+ ion. However, only about 4 in every 100 lactic acid particles dissociate.

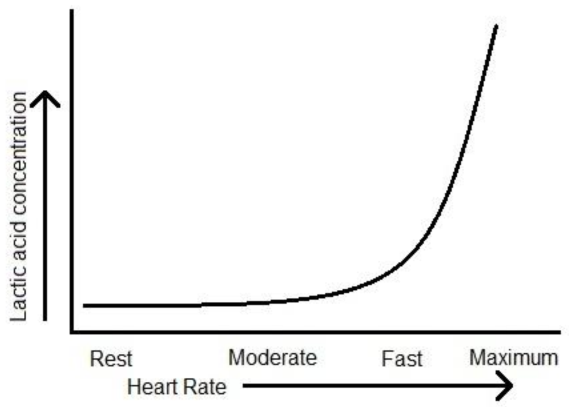
3. What is the molecular formula for lactic acid?

4. Estimate the pH of lactic acid.

5. Write the balanced symbol equation for the anaerobic respiration of glucose.

It is now well known how the lactic acid concentration in the blood varies with heart rate. Sports scientists make use of this information to help write athletes training programmes.

The blood lactate threshold is the heart rate at which lactic acid begins to build up in the blood and anaerobic respiration kicks in. If athletes know their blood lactate threshold, they can keep their heart rates below this level to prevent anaerobic respiration. This is why many athletes wear heart rate monitors during training.



6. Mark on the graph the blood lactate threshold.

Research Activity: Find out how an athlete would measure their blood lactate threshold. You could start by watching the faces of chemistry videos.

OR

Work through the ‘All-in-one Sports Drink’ activity sheet.