

Chemistry

NOW

This is a series of four leaflets which present modern aspects of chemistry in a way accessible to school students and directly usable by teachers. Each leaflet consists of four pages of information interspersed with questions to test student's understanding of what they are reading, to help them to link what they have read to the chemistry they already know and to help them to understand the text.

The leaflets could be used to support existing workschemes, to develop comprehension skills or as meaningful exercises to be used in the case of teacher absences (planned or unplanned).

The leaflets are:

•Chemistry and sport

This is aimed at 14–16 year olds and deals with the chemistry of aerobic and anaerobic respiration in the context of athletics and looks at a number of ways in which athletes can manipulate (legally!) the chemistry of this process to their advantage by monitoring the concentration of lactic acid in their blood.

•Chemistry of the atmosphere

This is aimed at 14–16 year olds. This looks at the way that the Earth's present atmosphere has evolved from possible earlier atmospheres. Some of the available evidence for different scenarios is presented and critically discussed.

•Computational chemistry

This is aimed at the post-16 age group. It presents a case study of the development of derivatives of cinnamic acid as a repellent to dissuade birds from eating crops treated with it. It explains how chemists develop relationships between structural features and particular types of activity and how computer modelling programmes are used in this work.

•Combinatorial chemistry

This is also aimed at the post-16 age group. Combinatorial chemistry is a group of techniques for synthesising large arrays of related chemicals. These can be easily automated by the use of robot syringes controlled by computers to carry out repetitive processes. The resulting arrays of chemicals called 'libraries' can then be screened for potential drug activities. Combinatorial chemistry is increasingly being used by pharmaceutical companies in their search for new drugs.

*Electron distribution
of cinnamamide*

Answers

For the use of teachers, answers to the questions on the leaflets are presented overleaf.

Chemistry and sport

One of the most amazing things about athletics is how World records continue to tumble – performances keep getting better. For example, the World record for the 100 m sprint is 9.79 seconds set by Maurice Greene in June 1999, and the Olympic record – set by Donovan Bailey at the 1996 Olympic Games in Atlanta – is 9.84 seconds. This is over two seconds better than the time of 12 seconds run in the 1896 Games – an improvement of about 20 per cent.

Chemists have contributed to these improvements in a number of ways. For example, the design of improved materials for clothing and equipment – eg poles for



▲
Donovan Bailey
setting the 1996
Olympic 100m
sprint record

FASTER AND FASTER

Performances in athletics events have steadily improved over the past 100 years as exemplified by the winning times in the Olympic men's 100 m sprint finals.

1896	Thomas Burke (US)	12.0 s
1900	Francis Jarvis (US)	11.0 s
1904	Archie Hahn (US)	11.0 s
1906	Archie Hahn (US)	11.2 s
1908	Reginald Walker (S Africa)	10.8 s
1912	Ralph Craig (US)	10.8 s
1920	Charles Paddock (US)	10.8 s
1924	Harold Abrahams (UK)	10.6 s
1928	Percy Williams (Canada)	10.8 s
1932	Eddie Tolan (US)	10.38 s
1936	Jesse Owens (US)	10.3 s
1948	Harrison Dillard (US)	10.3 s
1952	Lindy Remigino (US)	10.79 s
1956	Bobby Morrow (US)	10.62 s
1960	Armin Hary (FRG*)	10.32 s
1964	Robert Hayes (US)	10.06 s
1968	James Hines (US)	9.95 s
1972	Valeriy Borzov (USSR)	10.14 s
1976	Hasely Crawford (Trinidad)	10.06 s
1980	Allan Wells (UK)	10.25 s
1984	Carl Lewis (US)	9.99 s
1988	Carl Lewis (US)	9.92 s
1992	Linford Christie (UK)	9.96 s
1996	Donovan Bailey (Canada)	9.84 s

* FGR stands for the former Federal Republic of Germany.

Of course this list will soon be out of date. The internet is a good place to check up on changing information and one place to start with athletics records is

<http://www.hkkk.fi/~niininen/athl.html>

vaulting, spikes for running and even the track itself. Chemists are also involved in devising and monitoring the best methods of training for particular sports.

One example of this is the development of a performance test called the blood lactate threshold which helps endurance athletes – such as marathon runners – to train and prepare for competition and even helps them monitor their performance during an event.

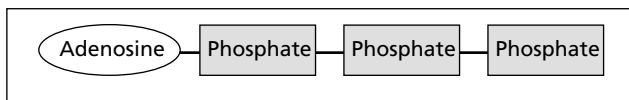
- Q1. What other factors will affect athletic improvement as well as biochemical ones
- Q2. Why is there not a steady increase in performance year on year?
- Q3. Try plotting a graph of the winning Olympic times against the year.
- Q4. Suggest why some of the times are recorded to one decimal place and others to two.

●The muscles' energy systems

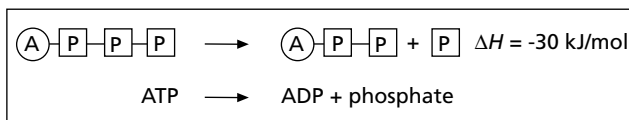
To understand the blood lactate test, we need to know something about the chemistry of how our bodies convert the chemical energy in our foods into mechanical energy, which makes our muscles contract.

The energy required for muscle contraction comes from a molecule called adenosine triphosphate (ATP, Fig 1).

In ATP, an organic (carbon-based) group called adenosine is attached to three



▲ **Figure 1**
An ATP molecule
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 of energy (Fig 2). This reaction



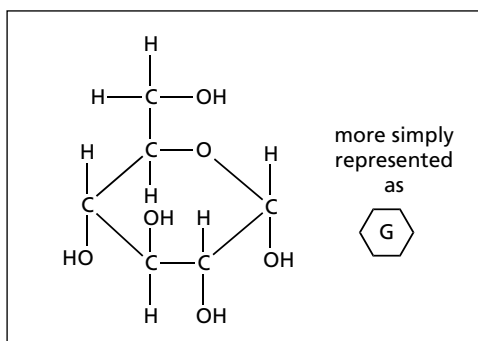
▲ **Figure 2**
The loss of a phosphate group from ATP
supplies the energy used to make our muscles contract. Surprisingly, we have only a relatively small amount of ATP in our muscles at any one time – even Olympic sprinters have enough for only two or three seconds of effort. So how can a sprinter complete a 10 second 100 m race, never mind a marathon runner keep going for over two hours?

The answer is that ATP is regenerated. The above reaction (Fig 2) is reversible and phosphate is re-attached to ADP to make ATP. This requires an input of 30 kJ/mol of energy. The energy for this comes from the breakdown of food molecules – carbohydrates (such as glucose, Fig 3), fats and proteins. The primary source is carbohydrates. These molecules store a great deal of energy (a mole of glucose (180 g) can release about 3000 kJ when reacted with oxygen). Our bodies release this energy gradually via the ATP/ADP cycle.

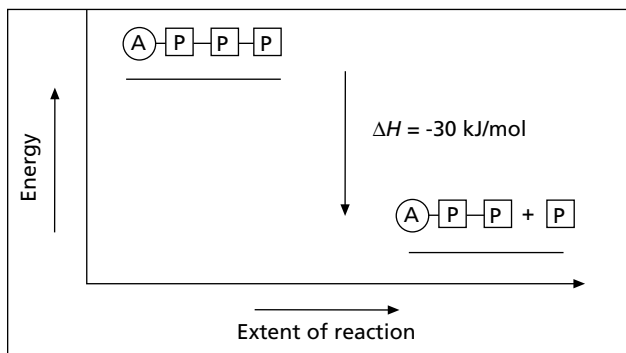
Q 5 a) What word is used to describe a reaction in which energy is; (i) given out; and (ii) taken in?

b) Figure 4 shows an energy level diagram for the formation of ADP and phosphate from ATP. Draw an energy level diagram for the regeneration of ATP from ADP and phosphate

► **Figure 3**
A glucose molecule



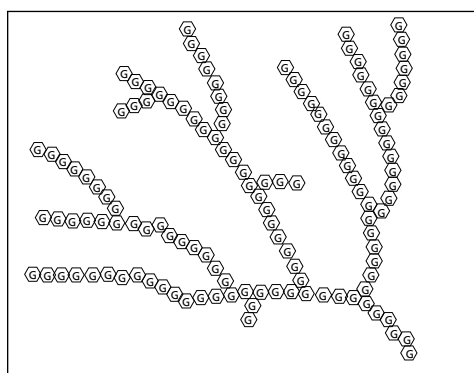
Q 6 a) How many molecules of ATP could be regenerated by one molecule of glucose if the process were 100 per cent efficient?



▲ **Figure 4**
Energy Level Diagram

b) In fact the process is only 40 per cent efficient. How many ATP molecules are actually regenerated by one molecule of glucose?

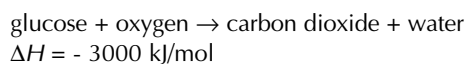
Glucose is stored in the muscles as a carbohydrate called glycogen, which consists of many glucose molecules linked together (Fig 5). Some endurance athletes make sure that they have a good supply of glycogen for an event by ‘carbohydrate loading’. They eat a lot of carbohydrate (rice, pasta, bread, potatoes etc) for a few days before an event.



◀ **Figure 5**
Part of a glycogen molecule

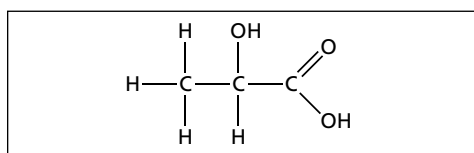
Our bodies have two ways of releasing the energy in glucose molecules – both processes are called respiration.

The first is called aerobic – ‘with air’ – respiration and uses oxygen to ‘burn’ the glucose to carbon dioxide and water



Q 7 Write the balanced symbol equation for the aerobic respiration of glucose, C₆H₁₂O₆.

The second is called anaerobic (‘without air’) respiration and involves splitting a glucose molecule into two molecules of lactic acid (Fig 6).



◀ **Figure 6**
Lactic acid molecule



blood. It is therefore the point at which anaerobic respiration kicks in. For endurance athletes, such as long distance runners, this threshold is very important. They rely on aerobic energy production to maintain their ATP level for long periods of time. If lactic acid builds up, they have moved into anaerobic energy production which can continue only for a short time. They must keep their heart rate (and therefore their exercise intensity) below this threshold to maintain their activity for a long period of time. If athletes know their blood lactate thresholds, they can keep their heart rates below them during an event. Many athletes monitor their heart rates during training and competition to do just this.

Suitable training can increase the blood lactate threshold – an untrained person's threshold is around 65 per cent of their maximum heart rate while a trained endurance athlete can achieve up to 90 per cent of their maximum heart rate.

Q10 On a copy of Fig 7; (a) mark the blood lactate threshold; and (b) sketch the graph you would expect for a trained endurance athlete.

At the moment, athletes can only measure their heart rate – not their lactic acid level – during competition. However, on-line sensors that measure lactic acid concentration in the blood directly may soon be available. These

will probably work by shining a beam of infrared radiation through the skin and through blood in the blood vessels. The radiation will be of a wavelength that is absorbed by lactic acid. The less intense the beam when it emerges, the more lactic acid there is in the blood. Such sensors might look like wrist watches. Sensors are currently being developed to measure blood glucose levels in people with diabetes, and lactic acid sensors will use similar technology.

Q 11 What is the advantage of measuring blood lactic acid levels during the race with an infra-red sensor? Are there any possible objections to this?

● Acknowledgements

This article is adapted by Ted Lister, with permission, from Mark Holmes, *On track to the Olympic games: Chemistry Giving the Winning Edge* in Australian chemistry Resource Book, Charles L. Fogliani (ed), p. 226. Queensland: Royal Australian Chemical Institute, 1998.

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