ATP, Life's energy currency and Metals in biological systems Tutorial

June 2009 Question 7

Metals play a vital part in biochemical systems. In this question you need to consider why some metals are essential to life, whilst others are toxic.

(a) For each of the metals, state where it might be found in a living organism, and what its chemical role is.

I. Iron Location in organism……………………………………………………………………..
Role………………………………………………………………………………………
……………………………………………………………………………………………….

II. Sodium Location in organism……………………………………………………………………….
Role………………………………………………………………………………………
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III. Zinc Location in organism……………………………………………………………………..
Role………………………………………………………………………………………
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(b) Heavy metals such as mercury are toxic, and it is important that these do not enter the food chain.

(i) Give a possible source of mercury in the environment.

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(ii) Describe and explain **two** reasons why mercury is toxic, using diagrams and/or equations to help your explanation.

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....[4]

[Total : 10]

June 2011 Question 8

(d) Copper is an important metal that has been used for thousands of years. The problem today is that most of the ores rich in copper compounds have been used up. A century ago ores containing >2% of copper by mass would have been worked; today's mines have to operate at much lower percentages, down to 0.5% of copper by mass.

(i) By what *type of reaction* is the copper present in the ore converted to copper metal?
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One of the main ores of copper contains the mineral *chalcopyrite*, $CuFeS_2$.

(ii) Calculate the percentage of copper by mass in *chalcopyrite*.

(iii) If the ore contains 2% of *chalcopyrite* by mass, calculate the mass of copper which can be produced from each tonne of ore.

(iv) Certain bacteria are able to extract copper from the 'spoil' heaps of previously mined copper ore. These bacteria are sprayed onto the spoil heaps in an aqueous solution and the resulting solution containing iron(II) sulfate and copper(II) sulfate is collected in tanks. Suggest how the copper could be recovered as metal.

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November 2007 Question 10

Read the following article about the use of bacteria in mining, and then answer the questions that follow it.

The discovery that bacteria could “mine” metals for us was made in Spain. The Rio Tinto mine, in the southwest corner of Spain, was originally mined for copper by the Romans some 2,000 years ago. In 1752, some mining engineers looked over the mine to see if it could possibly be re-opened. They noticed streams of a blue-green liquid running from spoil heaps of the processed rock that lay around the mine. When this blue-green liquid ran over iron, it coated the iron with a brown film. The brown film was metallic copper.

There was still some copper left in the spoil heaps. At the time, everybody thought that the copper was being dissolved in the liquid through a simple chemical reaction. But in 1947, US scientists discovered that the copper was being “mined” by a bacterium called *Thiobacillus ferrooxidans*.

The bacterium *Thiobacillus ferrooxidans* lives off the chemical energy trapped in metal sulphides. In the ore, the copper exists as copper sulphide. The bacteria gain energy by converting the copper sulphide to copper sulphate, which is then excreted. At the same time, they absorb the difference in energy in the chemical bonds. These bacteria can also obtain energy in similar reactions with ores of zinc, lead and uranium.

(a) Use the *Data Booklet* to explain why the blue-green liquid coated the iron with copper.
Write an equation for the reaction.

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.... [2]

(b) Suggest **two** reasons why this method of extracting copper might be useful for ore containing only a small percentage of copper.

(i)...

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(ii)..

....[2]

(c) Suggest **one** disadvantage of using bacteria rather than traditional mining and smelting methods.

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....[1]

(d) In conventional copper mining, the ore will typically contain 0.5 – 2.0% copper, which gives an idea of what a valuable resource copper is.

(i) The ore from a particular mine contains 0.75% copper, and 150 000 tonnes of ore are mined each year. From this ore about 60% of the copper is extracted, and the remainder is left in the 'spoil heaps' of processed ore.
What mass of copper is extracted each year?

(ii) If the use of bacteria can recover a further 17% of copper from the spoil heaps, what is the extra mass of copper produced?

[2]

(e) Suggest why bacteria are unlikely to be used in the extraction of aluminium.

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....[1]

(f) Metals like copper and zinc from abandoned mines can contaminate ground-water. Suggest **one** way of removing these contaminants.

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....[1]

[Total: 9]

<u>November 2010 Question 7</u>

Whilst small amounts of some metal ions are vital in the human body, others can be highly toxic.

(a) Hg^{2+} ions are toxic for a number of reasons. Hg^{2+} ions can react with the R–S–S–R group, which is found in proteins.

$R{-}S{-}S{-}R + 2Hg^{2+} + H_2\ 2\ R{-}S{-}Hg^{+} + 2H^{+}$ reaction 1

(i) What is the name of the R–S–S–R group in proteins?

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(ii) Which level of protein structure will be affected by reaction 1?

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(iii) Why will this affect the activity of an enzyme?

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....[3]

(b) Ag^+ ions can combine with free –COOH groups in the side chains of the amino acid residues in proteins to form partially covalent silver carboxylates.

RCOOH + Ag^+ RCOOAg + H^+ reaction 2

(i) What type of behaviour is the –COOH group showing in reaction 2?

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(ii) What types of R group interactions will be affected by reaction 2? Explain your answer.

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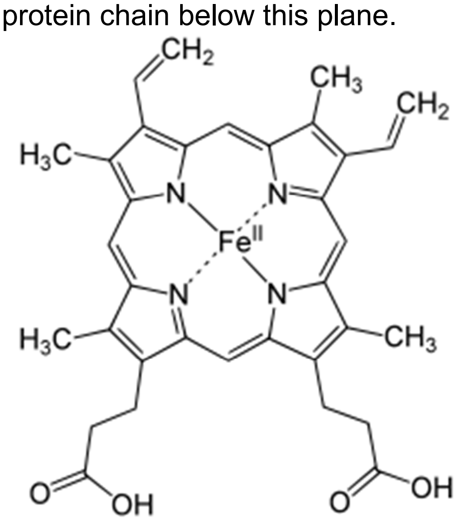
(c) By contrast, iron is an extremely important metal used in haemoglobin to transport oxygen molecules from the lungs to muscle cells and to carry carbon dioxide in the reverse direction.

One haemoglobin molecule contains four haem groups, each of which contains one iron atom. In the haem group four nitrogen atoms are in the same plane as the iron atom. The oxygen molecule is attached above this plane, and the iron atom is joined to a protein chain below this plane.



(i) How many oxygen **atoms** could one haemoglobin molecule transport?

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(ii) By what type of bonding is the oxygen molecule likely to be held to the iron atom in haem?

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(iii) What is the geometry of bonding around the iron atom?

....[3]