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A2 GCE APPLIED SCIENCE

G628/CS Sampling, Testing and Processing

PRE-RELEASE CASE STUDY – CANDIDATE INSTRUCTIONS

G611420111

INFORMATION FOR CANDIDATES

- This document consists of **8** pages. Any blank pages are indicated.

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Notes for Guidance

1. This pre-release Case Study contains two articles, which are needed in preparation for the externally assessed examination in Sampling, Testing and Processing.

2. You will need to read the articles carefully. In the examination, the first section of the paper will contain questions based on the two articles. You will be expected to apply your knowledge and understanding of the work covered in Unit G628 to answer these questions. The marks available for this section will be approximately 70% of the marks for the paper.

3. You can seek advice from your teacher about the content of these articles and you can discuss them with others in your class.

4. You will **not** be able to bring your copy of the Case Study material, or other materials, into the examination. The examination paper contains fresh copies of the two articles. You will find these as an insert in the examination paper. You will not have time to read these articles for the first time in the examination if you are to complete the paper within the specified time. However, you should refer to the articles when answering the questions.

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Titanium and titanium dioxide – materials for the space age

In 1791 black sands, occurring in a stream in Cornwall, were investigated. The sand was unusual in that it was weakly magnetic. Analysis showed that it contained an iron oxide and the oxide of an unknown metal. The mineral in the black sand became known as ilmenite, after a locality in the Ural Mountains of Russia. The unknown metal present was called titanium, after the Titans of Greek mythology. Although ilmenite contained titanium, it proved very difficult to extract metallic titanium, and it was not until 1910 that titanium was obtained in a pure state.

Titanium

Titanium also occurs in the mineral rutile, which is largely titanium dioxide. It is this mineral that is generally used to produce titanium metal because rutile is more easily processed than ilmenite and contains fewer impurities such as iron oxides. There are two main stages to this method of producing titanium.

(a) Rutile is mixed with coke and heated in a stream of chlorine gas at 1000 °C, forming titanium(IV) chloride (titanium tetrachloride).
(b) The titanium(IV) chloride (boiling point 135 °C) is purified and then the vapour reacted with molten magnesium, in a closed system, for two days. After cooling, the resulting mixture is added to dilute acid to remove other products, leaving titanium metal. The titanium metal is then purified by vacuum distillation.

The production of titanium by this method is an example of a batch process. World production of titanium by batch processes, such as this, amount to 96 000 tonnes each year.

Titanium metal has many uses. The most important properties of this metal are its strength (as strong as some steels), its relatively low density and its resistance to corrosion. Since titanium has excellent corrosion resistance and it is not prone to metal fatigue, it can be used as piping in power plants and in systems where there is exposure to salt water. These properties, and the fact that it is non-poisonous, means that titanium is not rejected by the body and it has an oxide film that bonds well to tissues. This allows surgeons to use titanium implants for bonding to bone.

Titanium dioxide

Titanium(IV) oxide (titanium dioxide) is a very important material. World production of this material is about 600 million tonnes annually. There are two methods for producing titanium dioxide from ilmenite and rutile – the sulfate process and the chloride process. A comparison of these two processes is seen in Table 1.

Table 1

sulfate process	chloride process
Uses basic chemical processing methods	Uses advanced technological procedures
Uses lower grade ore (ilmenite)	Higher grade ore (rutile) is necessary
Batch process	Continuous process
Large amount of less toxic waste materials produced	Uses toxic reagents but smaller quantities of waste materials are produced
Less pure titanium dioxide is produced	Pure titanium dioxide is produced

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Titanium dioxide also has many important uses. It is used as a white pigment in plastics, paint and paper. Some pharmaceutical tablets contain titanium dioxide as a filler and it is also extensively used in lipsticks. Many sunscreens contain titanium dioxide as it absorbs ultraviolet light and does not discolour. It has an advantage over many other chemical compounds used in sunscreens because it is much less likely to cause skin irritation. Some sunscreens contain 'larger' particles of titanium dioxide but their use leaves a white pasty appearance on the skin. Modern sunscreens contain titanium dioxide as nano-sized particles (diameter 10–100 nm) and there is less of a pasty appearance for those using them.

The effectiveness of sunscreens in absorbing ultraviolet radiation can be measured using an ultraviolet spectrophotometer. This instrument measures the absorption of ultraviolet radiation at various wavelengths as it passes through a thin film of sunscreen.
A typical spectrum is shown in Fig. 1.

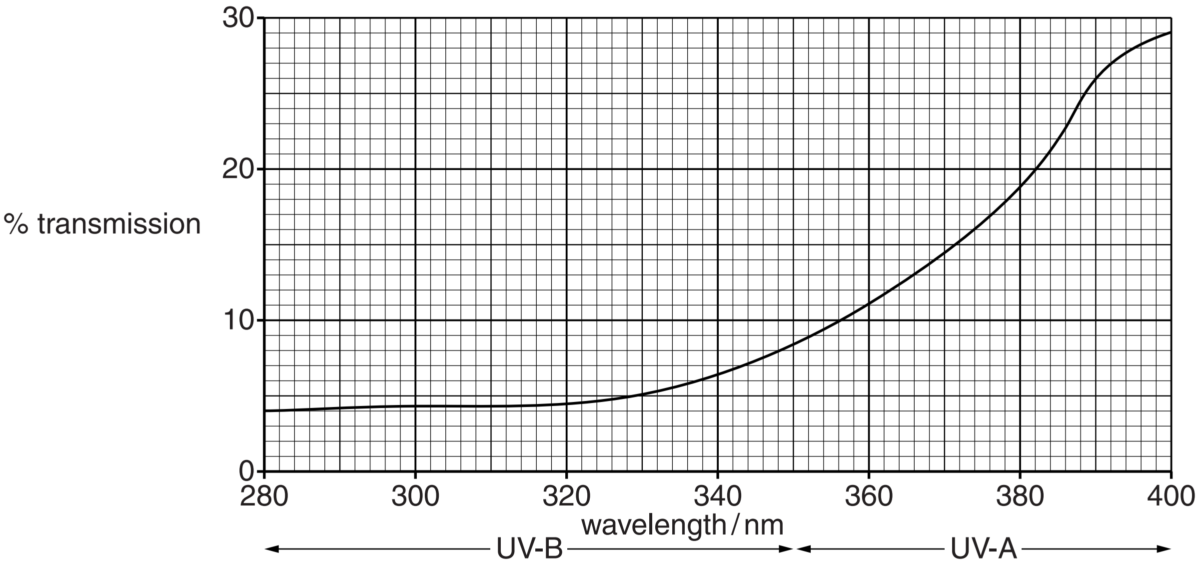

Fig. 1

The method can be used to compare the sun protection factor (SPF) of sunscreens but it is an '*in vitro*' system whereas actual use of the products on the skin is an example of an '*in vivo*' system.

The 'whiteness' of milk is due to suspended fat particles. There is interest in producing skimmed milk where all the fat has been replaced by substitute materials. In these products, titanium dioxide has been used as the 'whitening' agent, because skimmed milk without fat looks less attractive as it is not so white.

Analysis

The quantitative analysis of materials for titanium can be carried out in several ways. Some methods involve the precipitation of titanium dioxide and its subsequent weighing (gravimetric analysis). Another method uses colorimetry, where reaction of titanium ions with acidified hydrogen peroxide gives a yellow colour, whose intensity can be measured.

Titanium and its compounds have an increasingly wide range of applications – truly materials for the 21st century.

Water – an essential commodity

To many of us who live in Northern European countries, the problem of not having enough water does not often concern us. Global warming may produce more extreme weather conditions including more extensive periods of rain or dry weather. To many people who live in hotter countries, any extension of, already long, periods of drought will bring economic and ecological disaster on an unprecedented scale. It is essential, therefore, for those who have the technological capability, to prepare for such an eventuality and to provide for those who cannot.

Around two thirds of the planet is covered with water, but unfortunately, most of this water is saline and not suitable for drinking or for the irrigation of crops, see Fig. 2a.

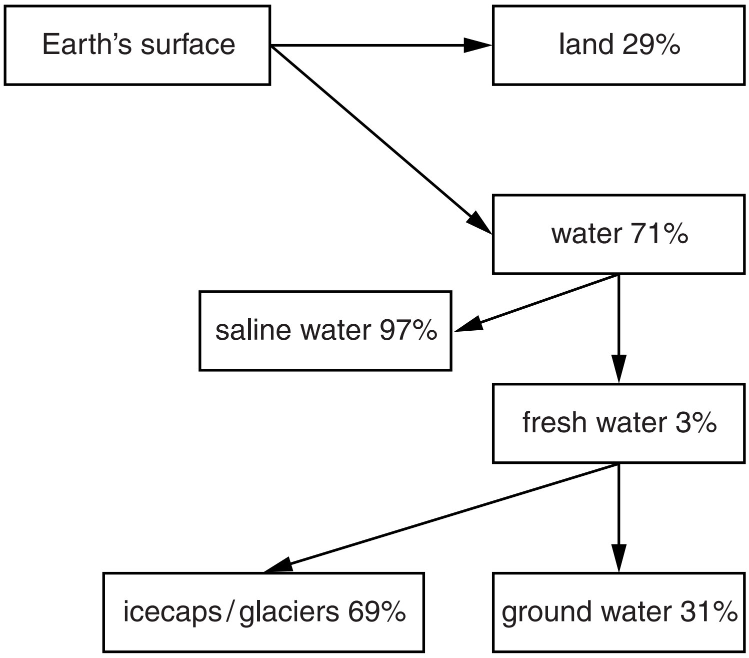

Fig. 2a

If the quantity of rain falling or present in rivers and lakes is insufficient for a people's needs, then it is essential to obtain water from the sea. The process of obtaining pure water from seawater is called desalination and the technology that enables this to be carried out is the subject of extensive ongoing research. Unfortunately, large-scale desalination uses huge quantities of energy and employs expensive technology, making it very costly when compared to the cost of purifying water from rivers, lakes and aquifers. As a result, desalination can generally only be adopted by those countries with large energy reserves, mainly in the Middle East. A plant in the United Arab Emirates is capable of producing 300 million (3×10^8) m^3 of fresh water each year. By way of contrast, the largest desalination plant in the United States only produces about 35 million m^3 each year.

There are two main ways of producing fresh water from seawater. These are by distillation and by those processes that use membranes (this includes reverse osmosis).

Details of these two types of desalination are shown in Table 2a.

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Table 2a

Distillation processes	Advantages	Disadvantages
Multi-stage flash distillation (MSF) Rapid evaporation on a series of heat exchangers	• Well developed technology used since the 1950s • Produces waste heat that can be reused	• High costs if 'waste heat' not available • Extensive corrosion problems
Multiple-effect evaporation (MEF) Similar to MSF but run at a reduced pressure	• Very efficient • Relatively inexpensive	• Large heating surfaces needed
Membrane processes		
Electrodialysis reversal (EDR)	• In use since the 1960s • Technology well developed • Very efficient	• High capital set-up and operating costs
Reverse osmosis (RO)	• In use since the 1980s • Reasonably efficient	• More pre-treatment of the seawater is needed than in MSF plants

In countries where there is extensive fresh water in rivers, lakes or aquifers, fresh water is purified rather than desalinating seawater. Much of this water is purified for human consumption as drinking water (potable water), but large quantities are also required for industry and commerce. In the world generally it is estimated that 1.1 billion people lack access to a safe drinking water supply. Sadly, 1.8 million people die each year from diarrhoeal diseases brought about by drinking unsafe water. Fresh water needs to go through several stages to produce water that is safe to drink and meets government standards for purity. These stages are summarised in Fig. 2b.

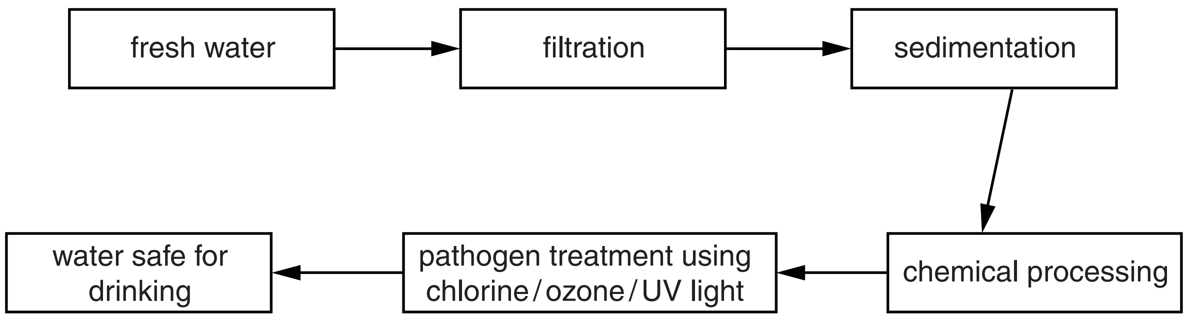

Fig. 2b

One advantage of using chlorine rather than just UV light for disinfecting the water, is that the chlorine remains in the water.

Drinking water is not pure water and still contains some soluble compounds, principally those of calcium and magnesium. There are also trace quantities of heavy metals and organic compounds but the water is continuously analysed to ensure that these materials are kept at, or below, acceptable limits.

Although the reserves of water on Earth are endlessly recycled through evaporation and condensation, the problem of producing safe water continues to be a major issue in many parts of the world.

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