



# Chemistry

## General Instructions

- Working time – 3 hours
- Board-approved calculators may be used
- Write using blue or black pen
- Draw diagrams using pencil
- A Data Sheet and Periodic Table are provided at the back of this paper
- Write your student number at the top of pages 7, 11, 15 and 19

## Total marks (100)

### Section I Pages 2 - 20

This section has two parts, Part A and Part B

#### Part A

Total marks (15)

- Attempt Questions 1 - 15
- Allow about 30 minutes for this Part

#### Part B

Total marks (69)

- Attempt Questions 16 - 29
- Allow about 2 hours for this Part

### Section II Pages 21 - 28

Total marks (16)

- Attempt ONE Question from Questions 30 - 34
- Allow about 30 minutes for this Section

## CHECKLIST

Each boy should have the following:

1 Question Paper

1 Multiple Choice Answer Sheet

1 4-page Writing Booklet

1 - MMB	2 - AKBB	3 - JAG	
4 - AKBB	5 - PRT	6 - JAG	7 - EPC

**Part A****Total marks (15)****Attempt ALL Questions****Allow about 30 minutes for this Part**

Use the multiple-choice Answer Sheet.

Select the alternative A, B, C or D that best answers the question. Fill the response circle completely.

**Sample**       $2 + 4 =$

(A) 2            (B) 6            (C) 8            (D) 9

(A)             (B)             (C)             (D)

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

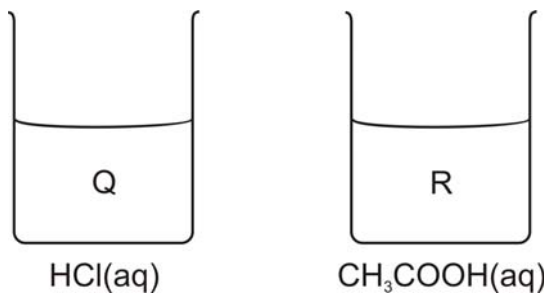
(A)             (B)             (C)             (D)

If you change your mind and have crossed out what you consider to be the correct answer, then indicate this by writing the word *correct* and drawing an arrow as follows.

(A)             (B)             (C)             (D)

*correct* →

1



Solution Q is a solution of hydrochloric acid (pH = 2.5), while solution R is a solution of acetic (ethanoic) acid (pH = 2.5).

Based on the above information and your knowledge of acids, which of the following statements is correct?

- (A) Solution R is stronger than solution Q.
- (B) Solution R is more concentrated than solution Q.
- (C) Solution Q is more concentrated than solution R.
- (D) Solution Q contains more H<sup>+</sup>(aq) than solution R.

2 Which of the following statements about ozone is valid?

- (A) Ozone depletion occurs only in the atmosphere above the South Pole.
- (B) Ozone is a vital gas in the stratosphere.
- (C) Ozone is a linear molecule.
- (D) Ozone is destroyed only by chlorofluorocarbons.

3 Which of the following types of radiation is the most penetrating?

- (A)  $\alpha$
- (B)  $\beta$
- (C)  $\gamma$
- (D)  ${}^1_0\text{n}$

4 At what point is equilibrium reached in a reversible reaction?

- (A) When reactants stop changing into products.
- (B) When the molar concentrations of reactants and products are constant.
- (C) When the molar concentrations of reactants and products are equal.
- (D) When the activation energy of the forward and backward reactions are the same.

- 5 A boy wished to classify lemon juice according to its acid/base characteristics. To do this he diluted some lemon juice and then added three drops of bromothymol blue. What colour would you expect this indicator to be in dilute lemon juice?
- (A) Red
  - (B) Yellow
  - (C) Blue
  - (D) Colourless
- 6 Which of the following is the most common anode in commercial primary galvanic cells?
- (A) Zinc
  - (B) Mercury(II) oxide
  - (C) Manganese dioxide
  - (D) Lead
- 7 Which of the following pairs of aqueous solutions will produce a precipitate on mixing?
- (A) Sodium chloride and potassium nitrate
  - (B) Lead(II) chloride and potassium nitrate
  - (C) Potassium carbonate and barium nitrate
  - (D) Copper(II) sulphate and sodium chloride
- 8 What is the common name for 2-hydroxypropane-1,2,3-tricarboxylic acid?
- (A) Acetic acid
  - (B) Hydrochloric acid
  - (C) Sulphuric acid
  - (D) Citric acid

9 Consider the following data:

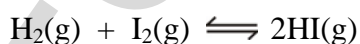
Half-reaction	$E^{\circ}_{\text{red}} / \text{V}$
$\text{W}^+ + \text{e}^- \rightarrow \text{W}$	2.3
$\text{X}^{3+} + \text{e}^- \rightarrow \text{X}^{2+}$	0.7
$\text{Y}^{2+} + 2\text{e}^- \rightarrow \text{Y}$	-0.7
$\text{Z}^{2+} + 2\text{e}^- \rightarrow \text{Z}$	-1.7

Using the data above, which of the following is the best reducing agent?

- (A) W
  - (B)  $\text{W}^+$
  - (C)  $\text{Z}^{2+}$
  - (D) Z
- 10 Which of the following needs to be monitored by industrial chemists working in coal-fired power stations?

- (A) Electricity generated by the station.
- (B) Rate of formation of ammonia from its elements.
- (C) Emission of steam and carbon dioxide.
- (D) Emission of carbon monoxide and sulphur dioxide.

11 Which of the following will affect the amount of hydrogen iodide gas present at equilibrium in this reaction?

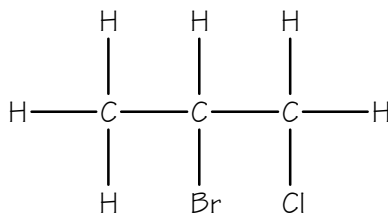


- (A) Adding a catalyst.
  - (B) Adding an inert gas.
  - (C) Increasing the pressure.
  - (D) Increasing the temperature.
- 12 Which of the following is the most commercially significant addition polymer?
- (A) Nylon
  - (B) PVC
  - (C) PET
  - (D) Starch

13 Which of the following statements about neutralization is correct?

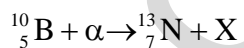
- (A) Neutralization is an electron transfer and is endothermic.
- (B) Neutralization is an electron transfer and is exothermic.
- (C) Neutralization is a proton transfer and is endothermic.
- (D) Neutralization is a proton transfer and is exothermic.

14 What is the IUPAC name of the following compound?



- (A) 2-bromo-3-chloropropane
- (B) 1-chloro-2-bromopropane
- (C) 2-bromo-1-chloropropane
- (D) 2-chloro-2-bromopropane

15 In the nuclear transformation below, what is X?



- (A) An electron
- (B) A proton
- (C) A neutron
- (D) A positron

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Class

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Student Number

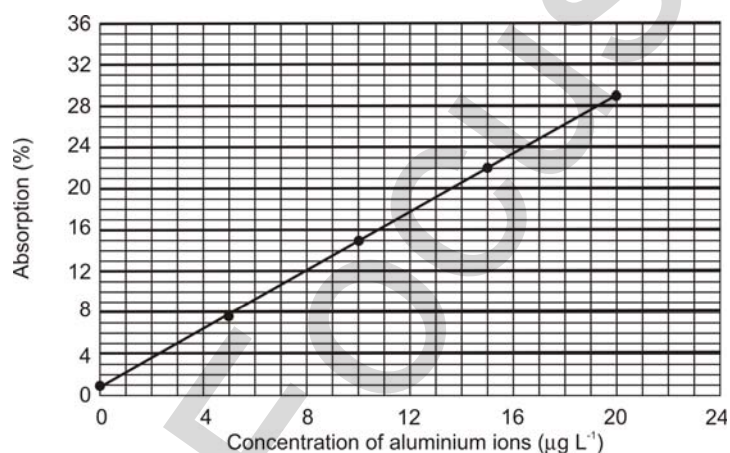
**Part B****Total marks (69)****Attempt ALL Questions****Allow about 2 hours for this Part**

Answer the questions in the spaces provided

Show all relevant working in questions involving calculations

**Marks****Question 16** (2 marks)

Atomic absorption spectroscopy (AAS) can be used as an analytical tool for finding the concentration of elements in the ppm range. The graph below shows the relationship of absorption against concentration of aluminium ions.

**2**

Use this graph to determine the  $\text{Al}^{3+}$  concentration in ppm for a sample which registered an absorption of 10%.

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**Marks****Question 17** (6 marks)

The equation  $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$  represents the synthesis of ammonia from its component gases and is known as the Haber process.

- (a) Describe the geo-political conditions under which Haber developed the industrial synthesis of ammonia and evaluate its significance at this time in world history. **3**

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- (b) Explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate and equilibrium. **3**

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**Marks****Question 18** (5 marks)

Atomic absorption spectroscopy (AAS) is an extremely useful tool in the detection of metal ion concentrations.

- (a) Explain why AAS is of little use in identifying unknown substances. **3**

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- (b) Explain how AAS has had a major impact on the scientific understanding of the effects of trace elements. **2**

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**Marks****Question 19** (6 marks)

The fermentation of glucose is a chemical process which has been known to humans for at least 5 thousand years.

(a) Write a chemical equation to represent the fermentation of glucose. **2**

(b) Under what physical conditions is fermentation optimised? **1**

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(c) One of the products of the fermentation process is frequently used as a solvent for both polar and non-polar solutes. Account for ethanol's ability to do this. **3**

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## Section I – Part B (continued)

Class									
Student Number									

**Marks****Question 20** (5 marks)

Fossil fuels, which at present make up the bulk of the raw material used in the plastics industry, are a finite resource and likely to become severely depleted in the near future. Biopolymers have been suggested as a possible replacement for the petrochemicals produced from fossil fuels.

- (a) Cellulose is often considered the most useful compound from which to produce biopolymers. Describe the structure of cellulose. **2**

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- (b) (i) Identify a biopolymer which has recently been developed or is in the process of being developed, for commercial use. **1**

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- (ii) Name the specific enzyme or organism used to synthesise this biopolymer. **1**

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- (c) Suggest one benefit (apart from their renewability), of using biomass to produce polymers. **1**

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**Marks****Question 21** (3 marks)

(a) Draw electron dot diagrams to show:

(i) an oxygen molecule.

**1**

(ii) an ozone molecule.

**1**

(b) State the difference in stability of ozone gas and oxygen gas.

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**Marks****Question 22** (3 marks)

Esters are produced by reaction of an alkanolic acid and an alcohol.

- (a) Name a straight-chained alkanolic acid. **1**

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- (b) Name a primary alcohol. **1**

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- (c) Name the ester that would be produced by refluxing this acid with this alcohol. **1**

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**Marks****Question 23** (7 marks)

Over time, the definitions of acids and bases have been refined. Using the historical development of ideas about acids, evaluate how advances in scientific understanding changed the direction of scientific thinking. 7

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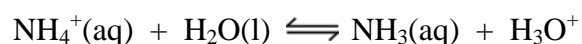
## Section I – Part B (continued)

Class									
Student Number									

**Marks****Question 24** (5 marks)

A student was investigating the acid/base nature of salts, by adding the dry solid salts one at a time to water and then testing their pH.

When he did this with ammonium chloride, he noted that the  $\text{pH} < 7$ , and assumed that the following action had occurred.



- (a) Why does the above equation illustrate a Brønsted-Lowry acid, rather than an Arrhenius acid? 2

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- (b) From the above equation, give one example of an acid and its conjugate base, respectively. 1

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- (c) Briefly outline how you would perform a first-hand investigation to determine the concentration of an acidic substance using a computer-based technology. 2

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**Marks****Question 25** (3 marks)

- (a) Identify two metallic ions which are found in hard water. **1**

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- (b) Describe a simple method of determining the hardness of water in a school laboratory. **2**

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**Marks****Question 26** (6 marks)

While we usually think of the air around us as neutral, the atmosphere naturally contains acidic oxides of carbon, nitrogen and sulfur.

- (a) (i) Describe, using an equation, an example of a chemical reaction which releases sulfur dioxide. **2**

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- (ii) Identify a natural source of sulfur dioxide. **1**

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- (b) (i) Describe, using an equation, an example of a chemical reaction which releases an oxide of nitrogen. **2**

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- (ii) Identify a natural source of nitric oxide (NO), a gas that is capable of destroying ozone, and is involved in the production of photochemical smog. **1**

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## Section I – Part B (continued)

Class									
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**Marks****Question 27** (4 marks)

- (a) Discuss the conditions under which nuclei are stable. 2

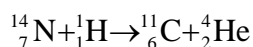
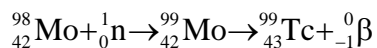
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- (b) The two equations below represent the formation of significant artificial isotopes: 2



Tc-99 is the most widely used radioactive isotope for diagnostic studies in nuclear medicine. C-11 is incorporated into organic compounds and used as a tracer in positron emission tomography (PET).

Discuss the production of commercial isotopes using these and / or other relevant examples.

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Marks

**Question 28** (6 marks)

Galvanic cells were constructed using the metals A – E and the voltages measured under standard conditions. The results are shown in the table below.

Cell reaction	$E^{\circ}_{\text{cell}} / \text{V}$
$\text{A} + \text{B}^{2+} \rightarrow \text{A}^{2+} + \text{B}$	0.98
$\text{B} + \text{D}^{2+} \rightarrow \text{B}^{2+} + \text{D}$	1.05
$2\text{C} + \text{B}^{2+} \rightarrow 2\text{C}^{+} + \text{B}$	1.68
$\text{B} + \text{B}^{2+} \rightarrow \text{B}^{2+} + \text{B}$	0.00
$\text{B} + \text{E}^{2+} \rightarrow \text{B}^{2+} + \text{E}$	0.66

- (a) Draw a labelled diagram of one of the cells used and identify clearly the reference cell.

3

- (b) Explain what is meant by standard conditions.

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**Question 28 continued on page 21**

**Marks**

## Question 28 (continued)

- (c) Construct a table of standard (half-cell) potentials from the data collected. **1**

- (d) (i) Identify the best reducing agent. **1**

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- (ii) Identify the best oxidising agent.

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**Marks****Question 29** (8 marks)

Polyethylene is a chemical which has been of significant commercial importance in the past fifty years.

- (a) Outline the major steps in the industrial production of polyethylene, from the raw material used, to the finished product. **3**

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- (b) Many commercial polymers are produced by the modification of ethene molecules, such that a hydrogen is replaced by a side group, followed by a polymerisation reaction. **3**
- (i) Identify one such “modified ethene” monomer, either by its common or systematic name, and using complete structural formula, write an equation to represent the polymerisation reaction, using **three** monomer units.

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**Question 29 continued on page 23**

**Marks**

## Question 29 (continued)

- (ii) Describe a use for the polymer you have identified, in part (i), in terms of its physical or chemical properties.

**2**

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**Section II****Total marks (16)****Attempt ONE question from Questions 30 - 33****Allow about 30 minutes for this Section**

Answer the question in a writing booklet. Extra writing booklets are available.  
Show all relevant working in questions involving calculations.

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	<b>Pages</b>
<b>Question 30</b>	<b>Industrial Chemistry ..... 27</b>
<b>Question 31</b>	<b>Shipwrecks and Salvage</b>
<b>Question 32</b>	<b>Biochemistry of Movement</b>
<b>Question 33</b>	<b>Chemistry of Art ..... 28-29</b>

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## Marks

**Question 30 - Industrial Chemistry (16 marks)**

- (a) Industrial chemists have researched and developed replacements for some natural products.
- (i) Identify one dwindling natural resource that is not a fossil fuel. **1**
  - (ii) Name a material that has been manufactured to replace the natural product identified in part (i). **1**
  - (iii) Explain why this replacement material is now manufactured. **1**
- (b)
- (i) Describe the use of sulphuric acid as a dehydrating agent. **1**
  - (ii) Explain how sulphuric acid may be used as an oxidant. **2**
- (c) Phosgene, or carbonyl chloride,  $\text{COCl}_2$ , is a colourless, poisonous gas used in the production of some polymers. Carbonyl chloride decomposes as shown in the following equation.
- $$\text{COCl}_2(\text{g}) \rightleftharpoons \text{CO}(\text{g}) + \text{Cl}_2(\text{g})$$
- 1.00 mol of carbonyl chloride was placed in a 10.0 L sealed flask at  $1250^\circ\text{C}$ . At equilibrium 0.20 mol of carbonyl chloride was present in the flask. Calculate the value of the equilibrium constant for the decomposition of carbonyl chloride at  $1250^\circ\text{C}$ .
- (d) Chemistry laboratories buy 18M (concentrated) sulphuric acid and dilute this so that they are able to make the concentrations needed for day-to-day analysis. **3**
- Explain how you would **safely** dilute 18M sulphuric acid to make 2M sulphuric acid. Include safety precautions.
- (e) Sulphuric acid is such an important chemical in industry that its annual production may be used as an index of a nation's industrial activity. **4**
- Explain why sulphuric acid is such an important industrial chemical using three different industrial uses of sulphuric acid.

**End of Question 30**

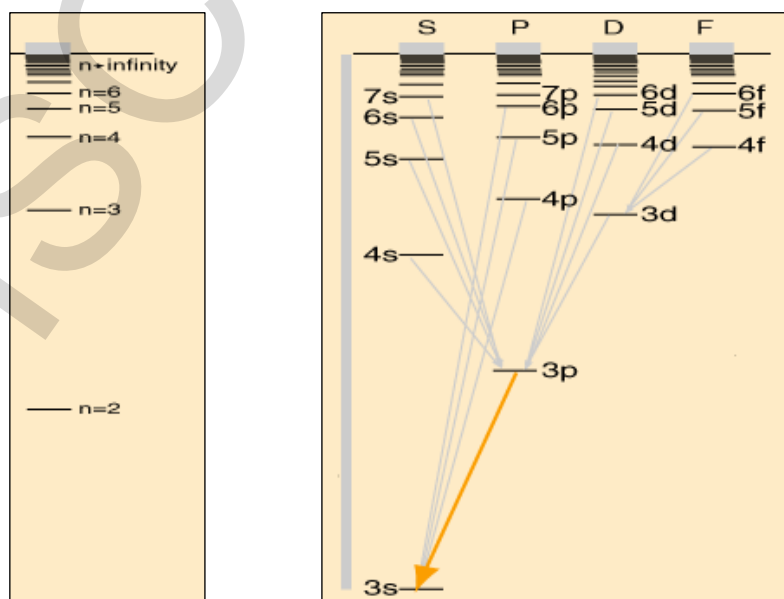
## Marks

**Question 33 - Chemistry of Art (16 marks)**

- (a) Modern cosmetics are carefully formulated to be beneficial to the skin, or at least not harmful, but this was not always the case. Some of the pigments used in ancient Egyptian, Greek and Roman make-up are given below.

Face make-up	White lead	$2\text{PbCO}_3 \cdot \text{Pb}(\text{OH})_2$
Lipstick	Cinnabar	$\text{HgS}$
Eye-shadow	Orpiment	$\text{As}_2\text{S}_3$
Mascara	stibnite	$\text{Sb}_2\text{S}_3$

- (i) What is the modern systematic name for orpiment? 1
- (ii) What are some of the safety hazards associated with these pigments? 2
- (b) (i) Identify the components of a paint. 1
- (ii) Outline the processes and chemistry involved to prepare and attach pigments to surfaces in a named example of a medieval or earlier artwork. 2
- (c) Explain the relationship between UV/visible absorption and reflectance spectra. 3
- (d) Explain the main features of atomic absorption and emission spectra, making reference to the energy level diagrams for sodium and hydrogen (see below). 3



**Question 33 continues on page 29**

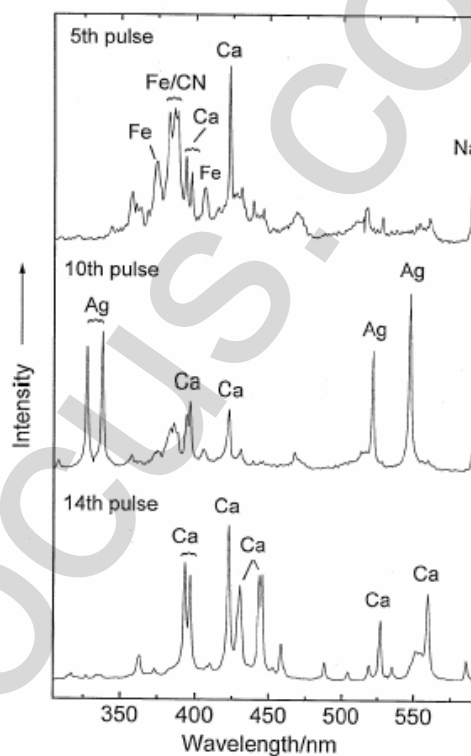
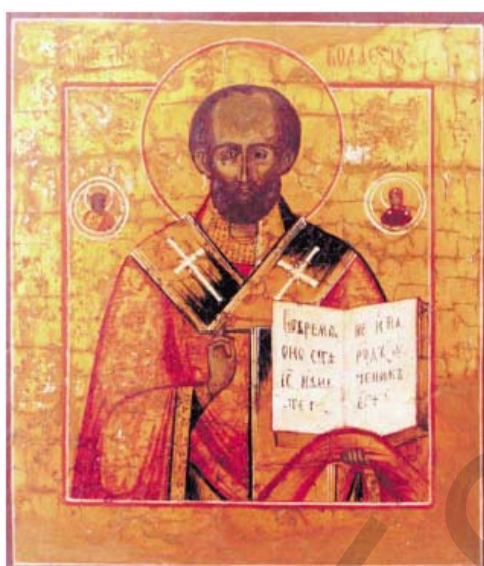
## Marks

## Question 33 (continued)

- (e) In laser microspectral analysis (LMA) a high energy laser pulse vaporises a minute amount of the material. Consecutive pulses dig deeper and deeper into the artwork, so that depth profiling is possible. The technique is very sensitive, using samples as small as  $10^{-7}$  g. It may also be coupled with other techniques that can identify the individual pigments.

4

## Russian icon of St Nicholas



The results of one LMA experiment on a nineteenth century Russian icon are shown above. A brown pigment in the paint is separated from the white ground by a metallic layer; the backing is wood.

Analyse the results and suggest compositions for the components of the three layers. Justify your answer.

**End of Question 33**

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# Chemistry

## Data Sheet

Avogadro's constant, $N_A$ .....	$6.022 \times 10^{23} \text{ mol}^{-1}$
Volume of 1 mole ideal gas: at 100 kPa and	
at 0 °C (273 K) .....	22.71L
at 25 °C (298K) .....	24.79 L
Ionisation constant for water at 25°C (298.15 K), $K_w$ .....	$1.0 \times 10^{-14}$
Specific heat capacity of water .....	$4.18 \times 10^3 \text{ Jkg}^{-1}\text{K}^{-1}$

### Some useful formulae

$$\text{pH} = -\log_{10}[\text{H}^+]$$

$$\Delta H = -mC\Delta T$$

### Standard Potentials

$\text{K}^+ + \text{e}^-$	$\rightleftharpoons$	$\text{K}_{(s)}$	-2.94 V
$\text{Ba}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Ba}_{(s)}$	-2.91 V
$\text{Ca}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Ca}_{(s)}$	-2.87 V
$\text{Na}^+ + \text{e}^-$	$\rightleftharpoons$	$\text{Na}_{(s)}$	-2.71 V
$\text{Mg}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Mg}_{(s)}$	-2.36 V
$\text{Al}^{3+} + 3\text{e}^-$	$\rightleftharpoons$	$\text{Al}_{(s)}$	-1.68 V
$\text{Mn}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Mn}_{(s)}$	-1.18 V
$\text{H}_2\text{O} + \text{e}^-$	$\rightleftharpoons$	$\frac{1}{2} \text{H}_{2(g)} + \text{OH}^-$	-0.83 V
$\text{Zn}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Zn}_{(s)}$	-0.76 V
$\text{Fe}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Fe}_{(s)}$	-0.44 V
$\text{Ni}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Ni}_{(s)}$	-0.24 V
$\text{Sn}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Sn}_{(s)}$	-0.14 V
$\text{Pb}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Pb}_{(s)}$	-0.13 V
$\text{H}^+ + \text{e}^-$	$\rightleftharpoons$	$\frac{1}{2} \text{H}_{2(g)}$	0.00 V
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^-$	$\rightleftharpoons$	$\text{SO}_{2(g)} + 2\text{H}_2\text{O}$	0.16 V
$\text{Cu}^{2+} + 2\text{e}^-$	$\rightleftharpoons$	$\text{Cu}_{(s)}$	0.34 V
$\frac{1}{2} \text{O}_{2(g)} + \text{H}_2\text{O} + 2\text{e}^-$	$\rightleftharpoons$	$2\text{OH}^-$	0.40 V
$\text{Cu}^+ + \text{e}^-$	$\rightleftharpoons$	$\text{Cu}_{(s)}$	0.52 V
$\frac{1}{2} \text{I}_{2(s)} + \text{e}^-$	$\rightleftharpoons$	$\text{I}^-$	0.54 V
$\frac{1}{2} \text{I}_{2(aq)} + \text{e}^-$	$\rightleftharpoons$	$\text{I}^-$	0.62 V
$\text{Fe}^{3+} + \text{e}^-$	$\rightleftharpoons$	$\text{Fe}^{2+}$	0.77 V
$\text{Ag}^+ + \text{e}^-$	$\rightleftharpoons$	$\text{Ag}_{(s)}$	0.80 V
$\frac{1}{2} \text{Br}_{2(l)} + \text{e}^-$	$\rightleftharpoons$	$\text{Br}^-$	1.08 V
$\frac{1}{2} \text{Br}_{2(aq)} + \text{e}^-$	$\rightleftharpoons$	$\text{Br}^-$	1.10 V
$\frac{1}{2} \text{O}_2 + 2\text{H}^+ + 2\text{e}^-$	$\rightleftharpoons$	$\text{H}_2\text{O}$	1.23 V
$\frac{1}{2} \text{Cr}_2\text{O}_7^{2-} + 7\text{H}^+ + 3\text{e}^-$	$\rightleftharpoons$	$\text{Cr}^{3+} + \frac{7}{2} \text{H}_2\text{O}$	1.36 V
$\frac{1}{2} \text{Cl}_{2(g)} + \text{e}^-$	$\rightleftharpoons$	$\text{Cl}^-$	1.36 V
$\frac{1}{2} \text{Cl}_{2(aq)} + \text{e}^-$	$\rightleftharpoons$	$\text{Cl}^-$	1.40 V
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^-$	$\rightleftharpoons$	$\text{Mn}^{2+} + 4\text{H}_2\text{O}$	1.51 V
$\frac{1}{2} \text{F}_{2(g)} + \text{e}^-$	$\rightleftharpoons$	$\text{F}^-$	2.89 V

PERIODIC TABLE OF THE ELEMENTS

KEY		Atomic Number	Symbol of element	Name of element
79	Au	197.0	Gold	
26	Fe	55.85	Iron	
25	Mn	54.94	Manganese	
24	Cr	52.00	Chromium	
23	V	50.94	Vanadium	
22	Ti	47.87	Titanium	
21	Sc	44.96	Scandium	
20	Ca	40.08	Calcium	
19	K	39.10	Potassium	
18	Ar	39.95	Argon	
17	Cl	35.45	Chlorine	
16	S	32.07	Sulfur	
15	P	30.97	Phosphorus	
14	Si	28.09	Silicon	
13	Al	26.98	Aluminium	
12	Mg	24.31	Magnesium	
11	Na	22.99	Sodium	
10	Ne	20.18	Neon	
9	F	19.00	Fluorine	
8	O	16.00	Oxygen	
7	N	14.01	Nitrogen	
6	C	12.01	Carbon	
5	B	10.81	Boron	
4	Be	9.012	Beryllium	
3	Li	6.941	Lithium	
2	He	4.003	Helium	

37	Rb	85.47	Rubidium	
38	Sr	87.62	Strontium	
39	Y	88.91	Yttrium	
40	Zr	91.22	Zirconium	
41	Nb	92.91	Niobium	
42	Mo	95.94	Molybdenum	
43	Tc	[98.91]	Technetium	
44	Ru	101.1	Ruthenium	
45	Rh	102.9	Rhodium	
46	Pd	106.4	Palladium	
47	Ag	107.9	Silver	
48	Cd	112.4	Cadmium	
49	In	114.8	Indium	
50	Sn	118.7	Tin	
51	Sb	121.8	Antimony	
52	Te	127.6	Tellurium	
53	I	126.9	Iodine	
54	Xe	131.3	Xenon	
55	Cs	132.9	Cesium	
56	Ba	137.3	Barium	
57-71			Lanthanides	
72	Hf	178.5	Hafnium	
73	Ta	180.9	Tantalum	
74	W	183.8	Tungsten	
75	Re	186.2	Rhenium	
76	Os	190.2	Osmium	
77	Ir	192.2	Iridium	
78	Pt	195.1	Platinum	
79	Au	197.0	Gold	
80	Hg	200.6	Mercury	
81	Tl	204.4	Thallium	
82	Pb	207.2	Lead	
83	Bi	209.0	Bismuth	
84	Po	[210.0]	Polonium	
85	At	[210.0]	Astatine	
86	Rn	[222.0]	Radon	
87	Fr	[223.0]	Francium	
88	Ra	[226.0]	Radium	
89-103			Actinides	
104	Rf	[261.1]	Rutherfordium	
105	Db	[262.1]	Dubnium	
106	Sg	[263.1]	Seaborgium	
107	Bh	[264.1]	Bohrium	
108	Hs	[265.1]	Hassium	
109	Mt	[268]	Mitlerium	
110	Uu	—	Ununilium	
111	Uut	—	Unununium	
112	Uub	—	Ununbium	
113	Uuq	—	Ununquadium	
114	Uuq	—	Ununquadium	
115	Uuh	—	Ununhexium	
116	Uuh	—	Ununhexium	
117	Uue	—	Ununseptium	
118	Uuo	—	Ununoctium	

Lanthanides

57	La	138.9	Lanthanum
58	Ce	140.1	Cerium
59	Pr	140.9	Praseodymium
60	Nd	144.2	Neodymium
61	Pm	[146.9]	Promethium
62	Sm	150.4	Samarium
63	Eu	152.0	Europlium
64	Gd	157.3	Gadolinium
65	Tb	158.9	Terbium
66	Dy	162.5	Dysprosium
67	Ho	164.9	Holmium
68	Er	167.3	Erbium
69	Tm	168.9	Thulium
70	Yb	173.0	Ytterbium
71	Lu	175.0	Lutetium

Actinides

89	Ac	[227.0]	Actinium
90	Th	232.0	Thorium
91	Pa	231.0	Protactinium
92	U	238.0	Uranium
93	Np	[237.0]	Neptunium
94	Pu	[239.1]	Plutonium
95	Am	[241.1]	Americium
96	Cm	[244.1]	Curium
97	Bk	[249.1]	Berkelium
98	Cf	[252.1]	Californium
99	Es	[252.1]	Einsteinium
100	Fm	[257.1]	Fermium
101	Md	[258.1]	Mendelevium
102	No	[259.1]	Nobelium
103	Lr	[262.1]	Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.  
The atomic weights of Np and Tc are given for the isotopes <sup>237</sup>Np and <sup>99</sup>Tc.