HSC Trial Examination 2002

Chemistry

This paper must be kept under strict security and may only be used on or after the morning of Tuesday 13 August, 2002, as specified in the NEAP Examination Timetable.

General Instructions

Reading time 5 minutes

Working time 3 hours

Write using blue or black pen.

Draw diagrams using pencil.

Board-approved calculators may be used.

A data sheet and a Periodic Table are provided at the back of this paper.

Examination structure

Section I Pages 2–20 Total marks 75

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 (60)
Attempt Questions 16–27.
Allow about 1 hour and 45 minutes for this part.

Section II Pages 21–27 Total marks 25

Attempt ONE question from Questions 28–32.
Allow about 45 minutes for this section.

Students are reminded that this is a trial examination only and cannot in any way guarantee the content or the format of the 2002 Chemistry Higher School Certificate examination.

 PO Box 214 St Leonards NSW 2065 Tel: (02) 9438 1386 Fax: (02) 9438 1385

Section I

Total marks 75

Part A

Total marks 15
Attempt Questions 1–15.
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.

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 draw an arrow as follows:

correct

A ~~●~~ B ~~●~~ C ○ D ○

1. In an aqueous solution of the weak acid nitrous acid, HNO_2, which of the following species is present in the highest concentration?
   (A) HNO_2
   (B) H_3O^+
   (C) OH^-
   (D) NO_2^-

2. The volume of a gas formed during an equilibrium process was monitored under various conditions. The following table summarises the results of these experiments.

Temperature (°C)	*Pressure* (kPa)		
	100	*200*	*300*
200	80 L	85 L	90 L
400	45 L	50 L	60 L
600	15 L	20 L	25 L

   Based on these results, what can be concluded about the reaction used to produce this gas?
   (A) It is exothermic and favours high pressures.
   (B) It is exothermic and favours low pressures.
   (C) It is endothermic and favours high pressures.
   (D) It is endothermic and favours low pressures.

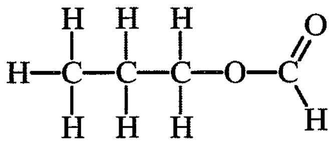
3. A solution of pH 9 has enough water added to it so that it now has a pH of 8. What effect does this have on the solution?
   (A) It becomes 10 times more concentrated and less alkaline.
   (B) It becomes 10 times more dilute and more alkaline.
   (C) It becomes 10 times more concentrated and more alkaline.
   (D) It becomes 10 times more dilute and less alkaline.

4. The following reaction is allowed to establish an equilibrium.

$$HF_{(aq)} + H_2O_{(l)} \rightleftharpoons F^-_{(aq)} + H_3O^+_{(aq)}$$

   When added to this equilibrium, which of the following soluble chemicals will **least** affect its position?
   (A) Copper (II) fluoride
   (B) Hydrogen chloride
   (C) Sodium hydroxide
   (D) Copper (II) nitrate

5. The following structure describes an ester.



Which organic reactants were used to form this ester?

(A) Methanol and propanoic acid

(B) 1-propanol and methanoic acid

(C) Ethanol and ethanoic acid

(D) 1-butanol and butanoic acid

6. The following table shows possible products from the decomposition of some organic compounds.

	Decomposition products	
Element from organic material	*By aerobic processes*	*By anaerobic processes*
carbon	carbon dioxide	methane
nitrogen	nitrate	ammonia
sulfur	sulfate	hydrogen sulfide

Stagnant (non-flowing) water tends to produce a strong odour while moving water does not. Which of the following best explains this?

(A) Water which flows mixes readily with oxygen, decreasing the solubility of anaerobically produced gases and so releasing these gases into the atmosphere.

(B) Water which flows mixes readily with oxygen, increasing the solubility of anaerobically produced gases keeping them in the water and so reducing odour.

(C) The aerobic processes of stagnant water produces strong smelling compounds.

(D) Oxygenation of water is promoted by the mixing of moving water with air, thus increasing the opportunity for aerobic decomposition.

Questions 7 and 8 are based on the following information.

A crystalline substance was tested to determine its composition. The following table summarises the tests performed and their corresponding results.

Test number	*Test Performed*	*Result*
1	physical appearance	blue solid
2	colour of aqueous solution	blue
3	colour of flame test	green
4	reaction with sodium chloride solution	no visible reaction

7. Based on these results, which ion could be present in the crystalline substance?

(A) Barium
(B) Copper
(C) Lead
(D) Sodium

8. Which test is least likely to identify the positive ion present in this crystalline substance?

(A) 1
(B) 2
(C) 3
(D) 4

9. Ethene is produced on a commercial scale by which process?

(A) Condensation
(B) Catalytic cracking
(C) Polymerisation
(D) Hydrogenation

10. While studying for an examination, a student came across the following quotes on the internet concerning anodes and cathodes.

Which of the following is the correct quote for her to learn?

(A) The anode in a galvanic cell is where oxidation occurs while an electrolytic cell has oxidation at the cathode.
(B) The anode in a galvanic cell is where reduction occurs while an electrolytic cell has reduction at the cathode.
(C) The anode in a galvanic cell is where oxidation occurs and an electrolytic cell also has oxidation at the anode.
(D) The anode in a galvanic cell is where reduction occurs and an electrolytic cell has oxidation at the anode.

11. Ethanol is a versatile and useful chemical. Which of the following processes is not an example of a use of ethanol?
(A) Oxidation as a fuel
(B) Miscible with water as a solvent
(C) Dehydration as a feedstock
(D) Fermentation

12. Which of the following equations shows a possible nuclear reaction in the decay series of U-238?
(A) $^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$
(B) $^{238}_{92}U \rightarrow {}^{234}_{90}Th + 2\,{}^{0}_{-1}e$
(C) $^{238}_{92}U + 2\,{}^{0}_{-1}e \rightarrow {}^{234}_{90}Th$
(D) $^{238}_{92}U + {}^{4}_{2}He \rightarrow {}^{234}_{90}Th$

Questions 13 and 14 are based on the following information.

For a practical test, a student carried out a series of titrations using hydrochloric acid to determine the concentration of household ammonia. The student used the 0.1 mol L^{-1} HCl provided for the titration and the household ammonia solution which had been diluted by a factor of 10. Three titrations were performed and the results were 12.3 mL, 12.5 mL and 12.3 mL. The expected concentration of the ammonia solution was 3% but the student's value was calculated to be 4.5%.

13. What should the student do to assess the validity of her results?
(A) Check the concentration of the 0.1 mol L^{-1} HCl against a primary standard.
(B) Perform more titrations and average the results.
(C) Use the full strength ammonia solution to obtain a more accurate result.
(D) Dilute the ammonia by a factor of 20 to obtain a more accurate result.

14. Which of the following reasons, given by other students, best justifies the difference between the calculated results and the expected value?
(A) Titration is not an accurate method.
(B) The difference between 3% and 4.5% is not significant.
(C) Titration is an accurate method and the solutions provided should be checked.
(D) Spectrophotometry would have been a more suitable method to determine concentration.

15. Following the contamination of water supplies in Sydney in 1998 with *Cryptosporidium* and *Giardia*, many residents now use membrane filters in their homes. The technology these filters use is based on which of the following assumptions?
(A) Water flows through the membrane, leaving dissolved substances behind.
(B) *Cryptosporidium* and *Giardia* are microorganisms and the filter pores are very small.
(C) Water can be forced to move through a membrane from low ion concentrations to high ionic concentration leaving contaminants behind.
(D) All of the above.

TENCH02.FM

Part B

Total marks 60
Attempt Questions 16–27.
Allow about 1 hour and 45 minutes for this part.

Answer Part B questions in the spaces provided.
Show all relevant working in questions that require calculations.

Question 16 (4 marks) **Marks**

You have studied the industrial use of electrolysis in refining a metal. For a named metal, outline this process and identify the oxidant, reductant and electrolyte used. Use relevant equations to justify your answer. **4**

....

....

....

....

....

....

....

....

Marks

Question 17 (4 marks)

A small amount of pure sodium metal is dropped into 1.2 L of water. The reaction is summarised in the following equation.

$$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$$

The gas collected occupied a volume of 4.68 L at 25°C and 1 atm pressure.

(a) Calculate the amount in moles of gaseous product. 1

....

....

....

....

....

(b) Calculate the final pH of the water. 3

....

....

....

....

....

....

Question 18 (4 marks)

The pH of human blood is maintained at about 7.4 by various buffers. One of the most important of these is the dihydrogen phosphate/hydrogen phosphate ($H_2PO_4^-/HPO_4^{2-}$) equilibrium.

(a) Write an equation for this equilibrium. 1

....

(b) With reference to this equation, explain how a solution containing this buffer could resist a change in pH if a small amount of acid were added to it. 3

....

....

....

....

....

....

Marks

Question 19 (8 marks)

The accuracy of acid-base titrations depends on several factors. These include the primary standard used, how the glassware is prepared and how the equivalence point is determined.

(a) Explain why sodium hydroxide is not used as a primary standard. 1

....

....

(b) Anhydrous sodium carbonate can be used as a primary standard. How can we ensure that the sodium carbonate remains anhydrous? 1

....

....

(c) During a titration, a conical flask is prepared by rinsing it with distilled water. While this flask is still wet, a clean, dry pipette is used to transfer 20 mL of a standard solution into it. Will the accuracy of the titration be affected? Explain your answer. 2

....

....

....

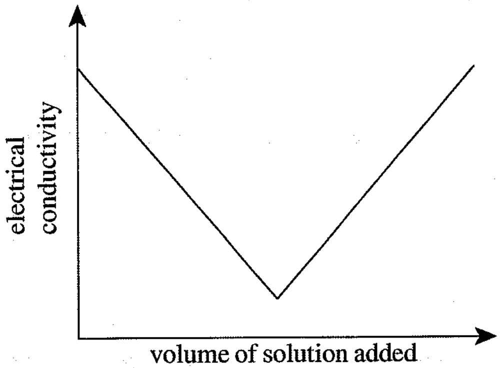
....

Question 19 continues on page 10

Marks

Question 19 (Continued)

(d) Although an indicator can be used to determine the equivalence point of an acid-base titration, an alternative method is to monitor the electrical conductivity of the reaction mixture during the titration. The following graph shows the variation in electrical conductivity during such a titration.



Explain why the electrical conductivity:

(i) starts at a maximum but then decreases to a minimum value. **2**

....

....

(ii) does not reach a zero value. **1**

....

....

(iii) starts to increase again after the minimum value. **1**

....

....

End of Question 19

Marks

Question 20 (5 marks)

An acid, HX, is prepared by dissolving 0.1 moles of it in enough water to make 1 litre of solution. A pH meter shows that the solution pH is 3.5.

(a) Calculate the $[H_3O^+]$ for the solution. **1**

....

....

....

(b) Explain whether HX is a weak or strong acid. **2**

....

....

....

(c) The salt, NaX, is dissolved in water. Predict whether the solution is acidic, neutral or basic, using an appropriate equation to justify your prediction. **2**

....

....

....

Marks

Question 21 (6 marks)

Some information about a radioactive isotope, X, is shown below.

Proportion of X remaining after decaying	
Time (hours)	*% remaining*
0	100
6	74
16	46
26	26
40	12
66	3

Characteristics of radiation emitted by X
Low ionising ability
Penetrates aluminium foil
Not deflected by electric field

(a) Draw a decay curve for X and use it to determine the half-life of X. 3

Question 21 continues on page 13

TENCH02.FM

Marks

Question 21 (Continued)

(b) Do you think X could be used in medical applications? Justify your answer. 2

. . . .

. . . .

. . . .

. . . .

(c) Suggest the identity of X. 1

. . . .

End of Question 21

Marks

Question 22 (5 marks)

Analyse the impact, both negative and positive, of radioisotopes on today's society. In your answer, you should refer to specific examples of the uses of radioisotopes in industry and medicine. 5

....

....

....

....

....

....

....

....

....

....

....

....

....

....

Marks

Question 23 (4 marks)

The physical properties of polymers are determined by their structure. Explain why some polymers soften upon heating. Name ONE polymer which behaves this way and describe how the property relates to its use. 4

Question 24 (5 marks)

Name ONE natural produced biopolymer and ONE artificially produced biopolymer. Describe briefly how the artificial biopolymer is produced and explain the benefits of biopolymers for society. 5

Marks

Question 25 (6 marks)

The successful growth of oysters is highly dependent on the quality of the water in which they are farmed. The following parameters need to be monitored to ensure water quality is maintained.

Parameter	
Minimum dissolved oxygen (ppm)	9.5
Maximum biochemical oxygen demand (ppm)	1.5
Maximum coliform (toxic) bacteria (number per 100 mL)	5
Maximum temperature (°C)	16
pH range	6.5–8.5
Maximum turbidity (NTU)	4

Table 1.

Analysis of water in a river gave the following readings.

Parameter	
Dissolved oxygen (ppm)	6.5
Coliform bacteria (number per 100 mL)	9500
Temperature (°C)	19
pH	4.3
Turbidity (NTU)	10

Table 2.

(a) Account for the relatively low dissolved oxygen reading in Table 2. **2**

....

....

....

(b) Predict the effect of the bacteria count on the biochemical oxygen demand in this river. Justify your answer. **2**

....

....

....

....

Question 25 continues on page 17

Marks

Question 25 (Continued)

(c) Evaluate the suitability of this river for growing oysters. 2

....

....

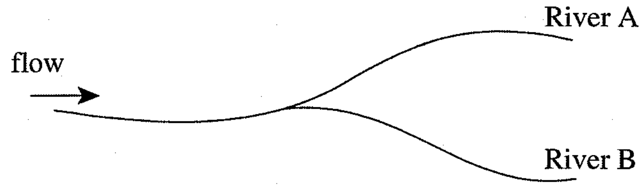
....

....

End of Question 25

Question 26 (4 marks) **Marks**

Samples of water were taken from two different rivers as shown. **4**



Analysis of the water was made to determine their relative concentrations of:

(i) dissolved oxygen.
(ii) phosphate ions.
(iii) lead ions.

River A is a healthy river, but River B shows signs of eutrophication.

Complete the table, and compare and account for the relative values of each of these concentrations.

Substance	*Concentration in River A relative to River B* (higher/lower/same)	*Explanation*
Dissolved oxygen		
Phosphate ion		
Lead ion		

 TENCH02.FM

Marks

Question 27 (5 marks)

Railways often test the cooling water of their diesel engines for dissolved metals. The presence of particular metal ions in the water gives an indication as to the "health" of the engine. The most commonly used method for this analysis is atomic absorption spectroscopy.

In one particular analysis a chemist was testing for the presence of iron. She used a series of standard solutions to obtain the following results.

Concentration of Fe (ppm)	*Absorbance* (%)
0	0.00
2	0.13
4	0.28
6	0.41
8	0.53
10	0.67

(a) Draw a calibration graph of these results. 1

Question 27 continues on page 20

Marks

Question 27 (Continued)

The chemist then tested the water from three engines.

For each engine she placed 50 mL of sample in a 1000 mL standard flask. The flask was then filled to the mark with distilled, deionised water and shaken to ensure mixing. She then tested each of the diluted samples and obtained the following results.

Engine Number	*Absorbance* (%)
X12	0.04
X45	0.01
X67	0.30

(b) Calculate the concentration of iron in the original sample from each engine. **2**

....

....

....

....

....

(c) Suggest an hypothesis for the variation of iron concentration for the different engines. **2**

....

....

....

....

End of Question 27

Section II

Total 25 Marks
Attempt ONE question from Questions 28–32.
Allow about 45 minutes for this section.
Answer the question in a writing booklet. Extra writing booklets are available.

Marks

Question 28 — Industrial Chemistry (25 marks)

(a) (i) Write the equilibrium constant expression for the following reaction. 1

$$2NO_{2(g)} \rightleftharpoons N_2O_{4(g)}$$

(ii) Explain how an equilibrium constant can have its value changed. 2

(b) Sulfuric acid is an important industrial chemical. It is produced on an industrial scale using the Contact process.

(i) Use appropriate equations to illustrate the steps involved in the conversion of elemental sulfur to sulfuric acid. 2

(ii) The step in the Contact process involving the production of SO_3 must be carefully controlled to ensure an economic yield is produced. Explain two of the conditions used to maximise the yield of SO_3. 2

(c) Compare and contrast the environmental impacts of soaps and synthetic detergents. 5

(d) (i) Identify the raw materials used in the Solvay process. 1

(ii) Outline the procedure for modelling the reaction of ammoniacal brine with carbon dioxide as part of the Solvay process in the school laboratory. 2

(iii) Describe a safety risk associated with the procedure you outlined in part (ii), and suggest a safe work practice to minimise the risk. 3

(e) Distinguish between the electrolysis methods used to extract sodium hydroxide by the mercury process and by the membrane process by describing each process and evaluating the technical and environmental difficulties involved in each process. 7

Marks

Question 29 — Shipwrecks and Salvage (25 marks)

(a) Briefly describe the work of one of Luigi Galvani, Humphry Davy or Michael Faraday in increasing the understanding of electron transfer reactions. **2**

(b) It is known that acidic environments accelerate corrosion in non-passivating metals.

(i) What is a non-passivating metal? **1**

(ii) With the use of a relevant half equation, explain how acidic environments accelerate their corrosion. **2**

(c) One method of preventing the corrosion of iron is coating it with a thin layer of another metal. Two such metals which have been used are zinc and tin. Using relevant half equations, determine which of these two metals would create a more effective protection to the iron if some of its protective layer were scratched off. **4**

(d) A student composed the following equation from a data sheet:

$$Fe_{(s)} + 2H_2O_{(l)} \rightarrow Fe^{2+}{}_{(aq)} + 2OH^-{}_{(aq)} + H_{2(g)} \qquad E = -0.42\ V$$

Based on this equation, the student concluded that it was possible for iron not to corrode in water.

(i) How does the student come to such a conclusion? **1**

(ii) Describe an experiment which you can perform that confirms the student's conclusion that iron will **not** corrode in water. **3**

(iii) With the use of relevant half equations, explain why iron normally rusts in water. **3**

(e) A solution of copper (II) chloride is electrolysed using inert graphite electrodes. At one of the electrodes, bubbles form. Analysis of these bubbles shows that two different gases are being formed, one of which is confirmed to be chlorine.

(i) In your answer booklet, draw a fully labelled diagram of the equipment used for this electrolysis. Include the direction of the electron flow, polarity of each electrode and the formation of the bubbles. **4**

(ii) With the use of a half equation, identify the other gas produced. **1**

(iii) As the reaction proceeds, other observable changes occur. Describe two of these changes and explain why they occur. **4**

Marks

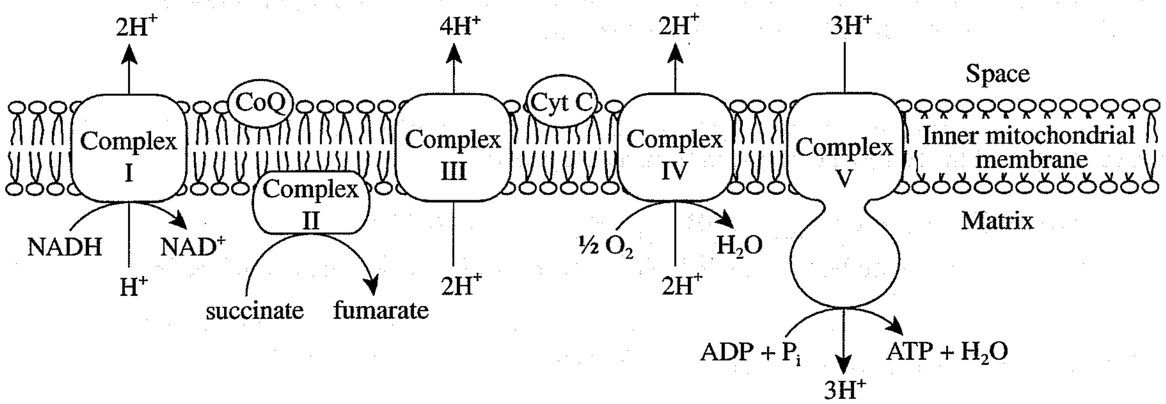
Question 30 — Biochemistry of Movement (25 marks)

(a) The energy stored in the ATP molecule comes from the breakdown of foods containing carbohydrates and fats. In this module you performed first hand investigations to determine the heat of combustion per mole of glucose and a named lipid. **3**

Justify the appropriateness of the particular investigation plan you used to determine the heat of combustion of either glucose or a named lipid.

(b) Describe the cause of the contraction movement in muscle and explain why ATP is consumed in the process. **4**

(c) A simplified flow chart of the biochemical pathways used to analyse the steps in oxidative phosphorylation is shown.



Analyse the flow chart and

(i) identify the role of oxygen. **1**

(ii) explain how the hydrogen is bonded to NAD^+ and what happens to the electrons when these bonds are broken. **2**

(iii) explain how the oxidation of NADH and $FADH_2$ is coupled to the production of high energy phosphate bonds in ATP. **2**

(d) Enzymes are proteins that catalyse biochemical reactions.

(i) Identify the changes that occur in the structure of an enzyme when exposed to conditions of pH or temperature outside its optimum range. **2**

(ii) Using a named example of an enzyme, explain why the enzyme's binding site is substrate specific. **2**

(iii) Explain the relationship between the production of 2-hydroxypropanoic acid (lactic acid) during anaerobic respiration and the impairment of muscle contractions by changes in cellular pH. **2**

(e) Identify a possible future direction of chemical research by biochemists interested in enhancing sports performance and evaluate its usefulness for the two extremes of exercise. **7**

 TENCH02.FM

Marks

Question 31 — Chemistry of Art (25 marks)

(a) Name a natural pigment that was used by Australian Aboriginals in the past and describe how it would be isolated and used by them. **3**

(b) Emission spectra were analysed by chemists and Niels Bohr developed the shell model to explain the spectrum produced by hydrogen. Relate the spectra obtained in the UV and visible regions to Bohr's model. **5**

(c) Explain, using NH_3 and Cu^{2+}, how the complex $[Cu(NH_3)_4.(H_2O)_2]^{2+}$ is able to form. Include a diagram as part of your explanation. **4**

(d) (i) The electron configuration for potassium can be shown as [Ar] $4s^1$. It can also be shown in box form as **3**

$$[Ar]\ \boxed{\uparrow}$$

Show the electron configurations for Fe and Fe^{2+} using both the orbital method and the orbital box form.

(ii) Solutions containing MnO_3^- are bright blue. The ion can be reduced to the dark solid MnO_2 in acidic solution. Write a half equation for this process and use it to explain why the colours are different. **3**

(e) A painting produced in medieval times would not use the same materials as one produced today. Discuss the major changes in materials used and describe a non-destructive technique which could be used to identify whether a painting is medieval or modern in origin. **7**

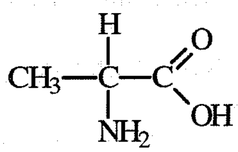
Marks

Question 32 — Forensic Chemistry (25 marks)

(a) (i) Describe an experimental test that could be used to distinguish between inorganic and organic compounds. 1

(ii) Name ONE class of organic compound that is of interest to forensic chemists and give the general formula. 2

(b) Alanine is a naturally occurring amino acid with the following structural formula.



(i) What is a protein? 1

(ii) Circle and name the major functional groups in this amino acid. 2

(c) Fats can be stored or produced in the human body. Vitamin D is an example of a lipid that is produced in the body. Lauric acid is an example of a lipid that is stored in the body. It is found in cow's milk and coconut oil.

(i) Give the general formula for a fatty acid. 1

(ii) Describe the difference between lipids that are produced by plants and those produced by animals. 2

(d) Maltose is a disaccharide that forms from a condensation reaction.

(i) Name a polysaccharide that forms from the same monomer. 1

(ii) Three food samples were collected for analysis. Each sample was tested with Benedict's solution, Tollen's reagent and iodine. Use the following information to identify which sample contains maltose. Explain your choice using chemical equations. 3

Sample	Benedict's Solution	Tollen's Reagent	Iodine
A	red-brick precipitate formed	silver mirror formed	remains yellow
B	no precipitate formed	no silver mirror formed	remains yellow
C	no precipitate formed	no silver mirror formed	turns blue-black

(e) (i) What conditions are necessary for atoms to emit light? 1

(ii) Explain what is meant by the term "signature line emission spectrum" and discuss how it can be used to identify elements in a sample for forensic analysis. 3

Question 32 continues on page 27

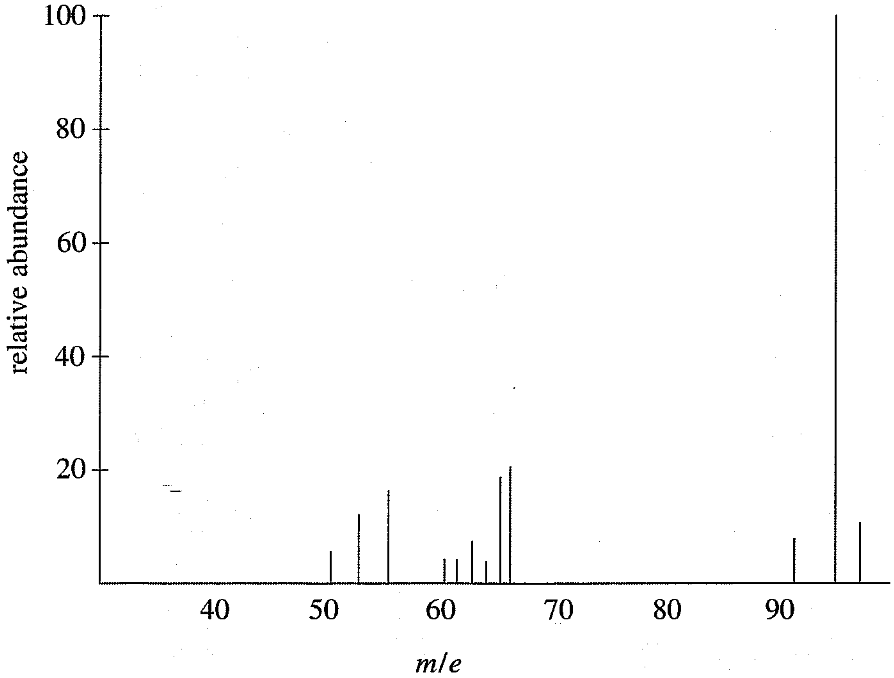
 TENCH02.FM

Marks

Question 32 (Continued)

(f) (i) Explain the importance of non-destructive testing in forensic analysis, giving an example of a situation where non-destructive testing would be required. **2**

(ii) Use the following information obtained from an analysis of a sample using mass spectroscopy to determine the relative molecular mass of the sample. **1**



(iii) Evaluate the use of mass spectroscopy in forensic analysis of small samples and compare this technique to scanning tunnelling microscopy. **5**

End of paper

Chemistry Data Sheet

Values of several constants

Avogadro's constant, N_A	6.022×10^{23} mol^{-1}
Volume of 1 mole of ideal gas at 101.3 kPa (1.00 atm)	
at 273 K (0°C)	22.41 L
at 298 K (25°C)	24.47 L
Ionisation constant for water	
at 298 K (25°C), K_w	1.0×10^{-14} mol^2 L^{-2}
Specific heat capacity of water	4.18 J K^{-1} g^{-1}

Useful formulae

$pH = -\log_{10}[H^+]$ $\qquad\qquad$ $\Delta H = mc\Delta T$

Standard potentials

$K^+ + e^- \rightleftharpoons K_{(s)}$	–2.94 V
$Ba^{2+} + 2e^- \rightleftharpoons Ba_{(s)}$	–2.91 V
$Ca^{2+} + 2e^- \rightleftharpoons Ca_{(s)}$	–2.87 V
$Na^+ + e^- \rightleftharpoons Na_{(s)}$	–2.71 V
$Mg^{2+} + 2e^- \rightleftharpoons Mg_{(s)}$	–2.36 V
$Al^{3+} + 3e^- \rightleftharpoons Al_{(s)}$	–1.68 V
$Mn^{2+} + 2e^- \rightleftharpoons Mn_{(s)}$	–1.18 V
$H_2O_{(l)} + e^- \rightleftharpoons \frac{1}{2}H_{2(g)} + OH^-$	–0.83 V
$Zn^{2+} + 2e^- \rightleftharpoons Zn_{(s)}$	–0.76 V
$Fe^{2+} + 2e^- \rightleftharpoons Fe_{(s)}$	–0.44 V
$Ni^{2+} + 2e^- \rightleftharpoons Ni_{(s)}$	–0.24 V
$Sn^{2+} + 2e^- \rightleftharpoons Sn_{(s)}$	–0.14 V
$Pb^{2+} + 2e^- \rightleftharpoons Pb_{(s)}$	–0.13 V
$H^+ + e^- \rightleftharpoons \frac{1}{2}H_{2(g)}$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_{2(aq)} + 2H_2O$	0.16 V
$Cu^{2+} + 2e^- \rightleftharpoons Cu_{(s)}$	0.34 V
$\frac{1}{2}O_{2(g)} + H_2O_{(l)} + 2e^- \rightleftharpoons 2OH^-$	0.40 V
$Cu^+ + e^- \rightleftharpoons Cu_{(s)}$	0.52 V
$\frac{1}{2}I_{2(s)} + e^- \rightleftharpoons I^-$	0.54 V
$\frac{1}{2}I_{2(aq)} + e^- \rightleftharpoons I^-$	0.62 V
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	0.77 V
$Ag^+ + e^- \rightleftharpoons Ag_{(s)}$	0.80 V
$\frac{1}{2}Br_{2(l)} + e^- \rightleftharpoons Br^-$	1.08 V
$\frac{1}{2}Br_{2(aq)} + e^- \rightleftharpoons Br^-$	1.10 V
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^- \rightleftharpoons H_2O_{(l)}$	1.23 V
$\frac{1}{2}Cl_{2(g)} + e^- \rightleftharpoons Cl^-$	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 36e^- \rightleftharpoons Cr^{3+} + \frac{7}{2}H_2O_{(l)}$	1.36 V
$\frac{1}{2}Cl_{2(aq)} + e^- \rightleftharpoons Cl^-$	1.40 V
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O_{(l)}$	1.51 V
$\frac{1}{2}F_{2(g)} + e^- \rightleftharpoons F^-$	2.89 V

PERIODIC TABLE

KEY

Atomic number Atomic mass	79 **Au** 197.0 Gold	**Symbol of element** Name of element

1 **H** 1.008 Hydrogen																	2 **He** 4.003 Helium
3 **Li** 6.941 Lithium	4 **Be** 9.012 Beryllium											5 **B** 10.81 Boron	6 **C** 12.01 Carbon	7 **N** 14.01 Nitrogen	8 **O** 16.00 Oxygen	9 **F** 19.00 Fluorine	10 **Ne** 20.18 Neon
11 **Na** 22.99 Sodium	12 **Mg** 24.31 Magnesium											13 **Al** 26.98 Aluminium	14 **Si** 28.09 Silicon	15 **P** 30.97 Phosphorous	16 **S** 32.07 Sulfur	17 **Cl** 35.45 Chlorine	18 **Ar** 39.95 Argon
19 **K** 39.10 Potassium	20 **Ca** 40.08 Calcium	21 **Sc** 44.96 Scandium	22 **Ti** 47.87 Titanium	23 **V** 50.94 Vanadium	24 **Cr** 52.00 Chromium	25 **Mn** 54.94 Manganese	26 **Fe** 55.85 Iron	27 **Co** 58.93 Cobalt	28 **Ni** 58.69 Nickel	29 **Cu** 63.55 Copper	30 **Zn** 65.39 Zinc	31 **Ga** 69.72 Gallium	32 **Ge** 72.61 Germanium	33 **As** 74.92 Arsenic	34 **Se** 78.96 Selenium	35 **Br** 79.90 Bromine	36 **Kr** 83.80 Krypton
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 Caesium	56 **Ba** 137.3 Barium	57–71 Lanthanides	72 **Hf** 178.5 Hafnium	73 **Ta** 180.9 Tantalum	74 **W** 183.9 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] Meitnerium	110 **Uun** – Ununnilium	111 **Uuu** – Unununium	112 **Uub** – Ununbium	113	114 **Uuq** – Ununquadium	115	116 **Uuh** – Ununhexium	117	118 **Uuo** – Ununoctium

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 Europium	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
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 masses are not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.

The atomic masses of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.