2001
PRIOR EDUCATION AUSTRALIA
EXAM 9

CHEMISTRY

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Board-approved calculators may be used
- Write using pencil
- Draw diagrams using pencil
- A Data Sheet and a Periodic Table are provided at the back of this paper

Section I

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 – 28
- Allow about 1 hour and 45 minutes for this part

Section II

Total marks **(25)**

- Attempt ONE question from Questions 29–33
- Allow about 45 minutes for this section

Section I
Total marks (75)

Part A

Total marks (15)
Attempt Questions 1-15
Allow about 30 minutes for this part

Use multiple-choice answer sheet.
Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

Sample 2 + 4 = (A) 2 (B) 6 (C) 8 (D)

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 ○

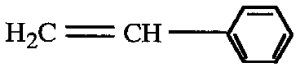
If you change your mind and have crossed out what you consider to be the correct answer. then indicate this by writing the word *correct* and drawing an arrow as follows:

A ✕ B ✕ ←*correct* C ○ D ○

1 Polystyrene is a hard plastic which is widely used in toys, recreational equipment and containers.

The monomer used to manufacture polystyrene is

(A)



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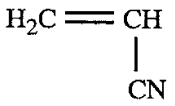

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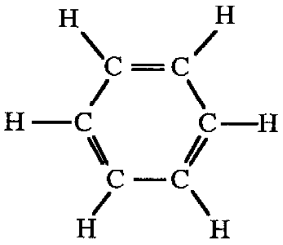
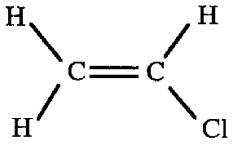


(D)



2 For use in industry, ethene is derived principally from

(A) fractional distillation of petroleum.

(B) the catalytic cracking of petroleum fractions.

(C) the dehydration of ethanol using concentrated sulphuric acid.

(D) the hydrogenation of ethane using platinum as a catalyst.

3 Which of the following nuclear equations relates to the production of a transuranic element in a nuclear reactor?

(A) $^{226}_{88}Ra \rightarrow {}^{226}_{82}Rn + {}^{4}_{2}He$

(B) $^{229}_{89}Ac \rightarrow {}^{229}_{90}Th + {}^{0}_{-1}e$

(C) $^{234}_{92}U + {}^{4}_{2}He \rightarrow {}^{230}_{90}Th$

(D) $^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{93}Np + {}^{0}_{-1}e$

4 The chemical equation which is the basis for the manufacture of ethanol from plant materials is

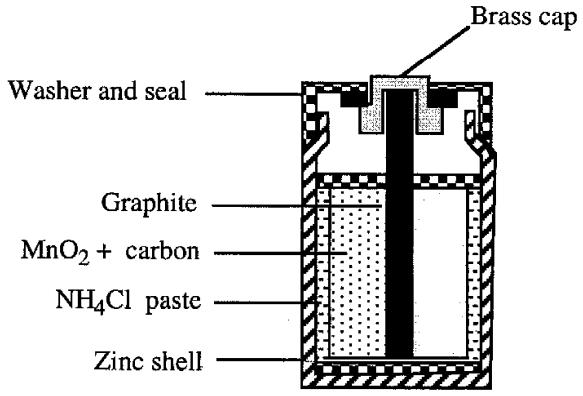
(A) $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + O_2$

(B) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

(C) $C_6H_{12}O_6 + O_2 \rightarrow 6CO_2 + 6H_2O$

(D) $2C_2H_5OH + 2CO_2 \rightarrow C_6H_{12}O_6$

5 There are a number of galvanic cells which are commonly used. A diagram of a dry or Le Clanche cell is illustrated below.



The overall reaction in this cell can be represented as

$$Zn_{(s)} + 2NH_4^+ + 2MnO_{2(aq)} \rightarrow Zn^{2+} + Mn_2O_{3(s)} + 2NH_{3(aq)} + H_2O_{(l)}$$

In this cell,

(A) Zn is acting as the cathode and is being reduced to Zn^{2+}.

(B) The manganese in MnO_2 is being reduced as its oxidation number changes from +4 to +3.

(C) The ammonium ion is acting as the oxidant.

(D) The graphite rod is negative.

6 The combustion of octane fuel may result in the formation of

(A) carbon dioxide gas

(B) carbon monoxide gas

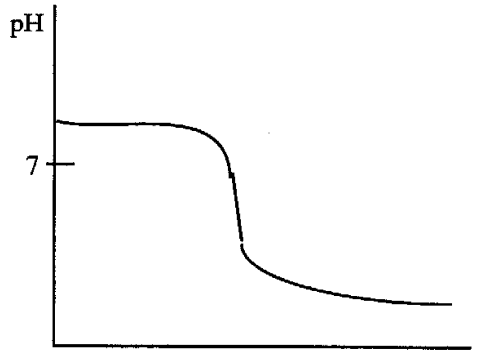
(C) carbon particles

(D) all of the above.

7 A 1.0 M solution of hydrochloric acid is titrated against solution of ammonia

$$NH_{3(aq)} + HCl_{(aq)} \rightarrow NH_4Cl_{(aq)}$$

The pH curve for the titration is shown below.



The equivalence point is at a pH

(A) less than 7 as the principal species at the equivalence point include the ammonium ion which is a Bronsted-Lowry acid.

(B) is 7 as the ammonia has neutralised the hydrochloric acid.

(C) is greater than 7 as hydrochloric acid is a strong acid and ammonia is a relatively weak base.

(D) is less than 7 as hydrochloric acid is in excess at the equivalence point.

8 Consider the following esterification reaction:

$$CH_3CH_2CH_2COOH + CH_3OH \rightleftharpoons H_2O + CH_3CH_2CH_2COOCH_3$$

Which of the following statements is correct?

(A) The yield of the ester formed could be increased by adding water.

(B) The yield of the ester formed would be reduced by adding a more concentrated solution of reactants.

(C) The reaction will not occur if the reactant's solution is not refluxed.

(D) The yield of the ester formed could be increased by adding sulphuric acid.

9 Which of the following species may act as a Lewis base?

(A) boron trifluoride

(B) the hydrogen ion (H^+)

(C) ammonia

(D) none of the above

10 The organic compound with the lowest boiling point is

(A) ethene.

(B) ethanoic acid.

(C) ethyl ethanoate

(D) ethanol.

11 Which one of the following is a correctly named isomer of 2-bromobutane?

(A) 1-bromomethylpropane

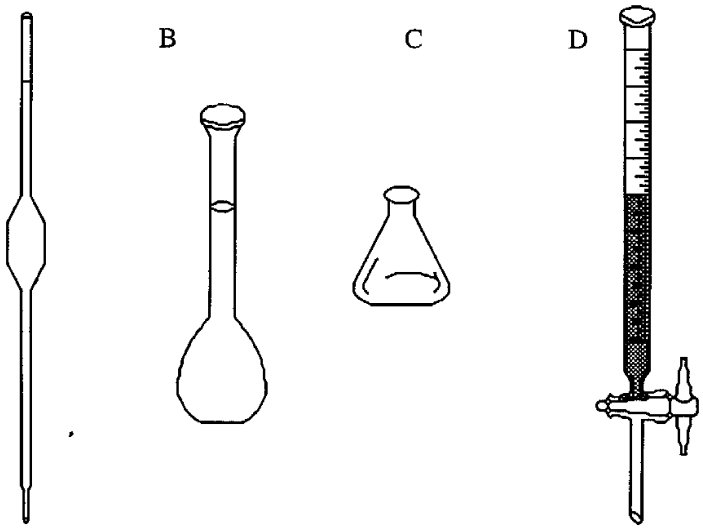
(B) 3-bromobutane

(C) 1-chlorobutane

(D) 2-bromopropene

12 Which of the following laboratory apparatus would be used to accurately measure an aliquot of solution for titration?

A B C D



13 Ammonia may be produced through the gentle heating of ammonium chloride and calcium hydroxide in a small amount of water.

$2NH_4Cl_{(aq)} + Ca(OH)_{2(aq)} \rightarrow 2NH_{3(aq)} + CaCl_2 + 2H_2O_{(l)}$

Which of the following statements is CORRECT?

(A) The reaction is a condensation reaction.

(B) Once the reaction has occurred, the resulting mixture is neutral.

(C) The ammonium ion is acting as a Bronsted-Lowry acid as it is dontaing a proton to the hydroxide ion.

(D) The production of ammonia using this reaction is commonly referred to as the Haber process.

14 A student analyses a sample of water from a local river for a number of ions. His results are summarised in the table below.

Test	Result
addition of barium nitrate solution	white precipitate forms
addition of silver nitrate solution	white precipitate forms

The identity of the two precipitates is likely to be

(A) barium sulphate and silver chloride.

(B) sodium nitrate for both.

(C) barium oxide and silver bromide.

(D) magnesium nitrate and lead nitrate.

15 The composition of **clean** air at **sea level** is

(A) 78 % oxygen, 21% nitrogen, <1% water, carbon dioxide and argon.

(B) 78 % nitrogen, 21% oxygen, <1% water, carbon dioxide and argon.

(C) 75% nitrogen, 18% oxygen, 7% carbon dioxide

(D) 100% oxygen

Section I

Part B

Total marks (60)
Attempt Questions 16-28
Allow about 1 hour and 45 minutes for this part

Answer the questions in the spaces provided
Show all relevant working in questions involving calculations.

Question 16 (7 marks) **Marks**

Consider an experiment where the following electrochemical (galvanic) cell is set up.

$Sn_{(s)} / Sn^{2+}_{(aq)}$ 1M // $KNO_{3\,(aq)}$ // $Mg^{2+}_{(aq)}$ 1M/ $Mg_{(s)}$

(a) Draw a neat diagram of the cell that would set up and include the following labels: **2**

* anode and cathode

* salt bridge, including the direction of movement of the ions

* the direction of electron flow between anode and cathode.

Question 16 continues over the page

Question 16 (continued) **Marks**

(b) Write the overall equation for the reaction which occurs. **1**

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(c) By referring to the table of standard reduction potentials, calculate the initial potential of the cell. **2**

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(d) What is the purpose of the potassium nitrate solution? **2**

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Question 17 (4 marks) **Marks**

Condensation biopolymers are being considered as an alternative source of compounds obtained currently from the petrochemical industry.

(a) What is a condensation polymer? **2**

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(b) Describe the structure of one condensation biopolymer you have come across in your studies. **2**

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Question 18 (5 marks) **Marks**

Ethanol can be added to petrol and used in cars without any modifications. To produce the ethanol, the fermentation process is used in which carbon dioxide gas is also a product.

(a) Write a balanced equation for the process, using glucose ($C_6H_{12}O_6$) as the sugar being fermented, in the absence of oxygen. **1**

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(b) If 0.5 mole of ethanol is burnt in air, 680 kJ of energy is released. Write a balanced chemical equation for this reaction and include the energy term. **2**

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(c) The combustion of fuels such as ethanol often sometimes results in the formation of the pollutant carbon monoxide gas. Under what conditions does this occur? **2**

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Question 19 (5 marks) **Marks**

The table below shows the atmospheric levels of different gases in two different urban areas.

Component of air	Clean air	Urban Area P	Urban Area Q
Ozone (ppm)	0.02	0.22	0.05

(a) Calculate the concentration of ozone gas in urban area P in $molL^{-1}$. Assume the atmospheric pressure was 101.3 kPa and the temperature 298 K when the measurements were taken. **2**

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(b) Urban area P has elevated ozone levels.

(i) Suggest a possible source for the ozone gas. Write a balanced chemical equation or equations for the formation of ozone gas. **2**

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(ii) What environmental / health impact may this have? **1**

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Question 20. (6 marks) **Marks**

An analytical chemist wanted to determine the sulfate content in an all purpose fertiliser. He weighed out 10.1 g of the lawn fertiliser. He dissolved this fertiliser in 200 mL of 0.9 M HCl, and filtered off any fertiliser that did not dissolve. To the remaining solution he added barium chloride, stirring with a glass rod. He found that a white precipitate formed. After washing this precipitate with distilled water and drying it in an oven, it had a mass of 4.84 g.

(a) Write a balanced chemical equation for the formation of precipitate. **1**

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(b) Draw a fully labelled diagram of the apparatus you would use to separate the precipitate from the aqueous mixture. **2**

(c) Determine the percentage sulfate in the fertiliser (by mass). **3**

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Question 21 (4 marks) **Marks**

Consider the following species.

CO_3^{2-} H_2SO_4 NH_3 OH^- NH_4^+

(a) Which species will act as Lowry-Bronsted bases? Why? **2**

CO_3^{2-} , NH_3

(b) Write a equation to show the species you selected in part (a) acting as a base with one of the other species listed. **1**

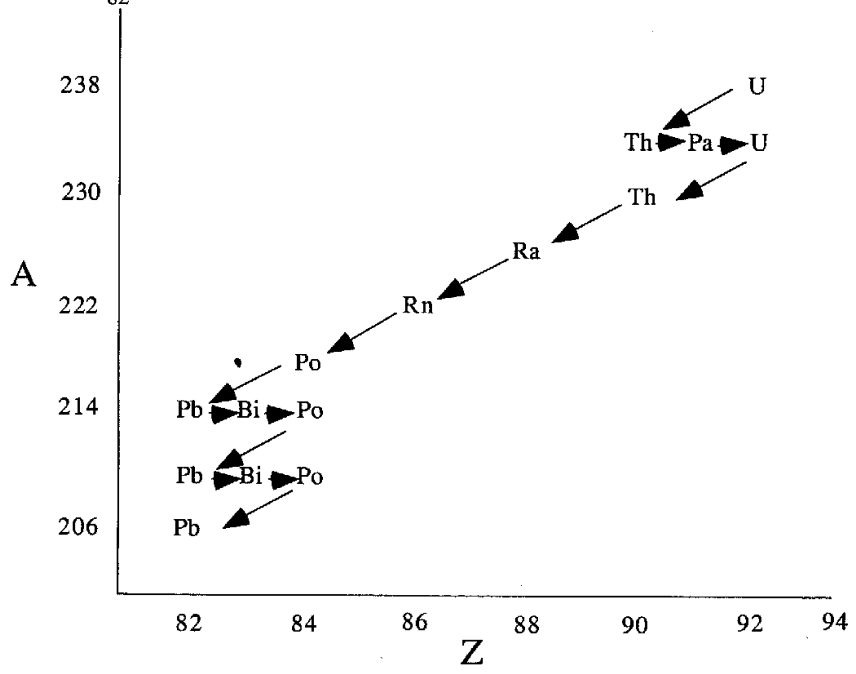
$CO_3^{2-} + NH_4^+ \longrightarrow HCO_3^- + NH_3$

(c) Which species is amphiprotic? **1**

NH_3

Question 22 (3 marks) **Marks**

The following series shows how the element uranium decays to the stable isotope, $^{206}_{82}Pb$.



(a) What do the symbols Z and A on the y and x axes represent? **2**

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(b) Write a nuclear equation for the first step of the series (the alpha decay of uranium-238 decays to thorium). **1**

Question 23 (5 marks) **Marks**

A titration is carried out in which a 0.5 $molL^{-1}$ sodium hydroxide solution in a burette is titrated against 20 mL of sulfuric acid solution. The volume of base required to reach the end-point was 12.5 mL.

(a) State how you would determine experimentally when the end point of the titration had been reached. **2**

identify species H_2SO_4 + NaOH pH 7
add app. indicator a few drops Bromo Blue.
when titrating with SA first
sign of colour change permanent

(b) Write a balanced chemical equation for the neutralisation reaction. **1**

$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

(c) Calculate the concentration of the sulfuric acid solution. Show *all* working. **2**

$H_2SO_4 + 2NaOH \longrightarrow Na_2SO_4 + 2H_2O$

C 0.1562 0.5

N 3.125 N = 0.25

V 20 mL 12.5

Question 24 (5 marks) **Marks**

Many oxides show acidic or basic properties when placed in water.

(a) Write the formulae of the oxides of the elements in the third period of the Periodic Table. **2**

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(b) Describe the trend in the acidic/basic nature of the third period oxides. Your answer should include chemical equations to show the acidic/basic nature of at least one basic oxide and one acidic oxide. **3**

$Na_2O + H_2O \longrightarrow NaOH$

$CO_2 + H_2O \rightarrow H_2CO_3$

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Question 25 (6 marks) **Marks**

An iron ore based company uses ta man made pond as a water supply in its iron manufacturing process. Once being used to cool down their steel works the water is returned to a water storage pond for reuse.

(a) How would you measure the dissolved oxygen content of the water in the pond? **2**

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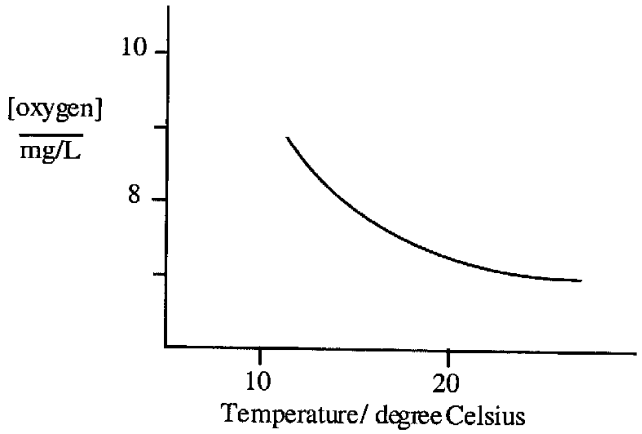
(b) Considering the following graph, what effect would the fact that the water is used as a coolant have on the dissolved oxygen content in the pond? **1**



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Question 25 is continued over the page

Question 25 (continued) **Marks**

(c) Define the term biological oxygen demand (BOD). How is BOD measured? **3**

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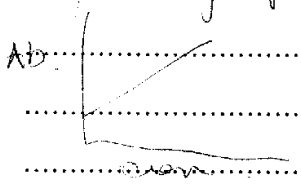
Question 26 (3 marks) **Marks**

Describe the use of atomic absorption spectroscopy (AAS) in the analysis of water samples. **3**

AAS helps us find [ ] of metal ions in water sample. Only small [ ]

Draw graph:



Question 27 (3 marks) **Marks**

In your studies you have come across a number of catalysts. **3**

Name one such catalyst and the reaction it which it is employed. **Describe** the role of the catalyst in this reaction and **propose** a model to account for its effect.

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Question 28 (4 marks) **Marks**

The pH of two equimolar solutions is summarised in the table below.

Acid	0.1 M HCl	0.1 M CH_3COOH
pH	1.0	2.87

(a) Calculate the $[H^+]$ for each solution. **2**

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(b) Account for the difference in pH of each solution. **2**

Eqn's Acetic ⇌

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Section II

Total marks (25)
Attempt ONE question from Questions 29-33
Allow about 45 minutes for this part

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

Question 29 -- Industrial Chemistry (25 marks) **Marks**

(a) (i) Draw a flowchart outlining the steps in the double contact sulphuric acid manufacturing process. **3**

(ii) Describe one way in which heat energy is conserved in the process. **1**

(iii) Sulphuric acid can act as an oxidising agent. Write down the reaction between solid zinc metal and;

(α) dilute sulphuric acid **1**

(β) concentrated sulphuric acid **1**

(iv) Dilute sulphuric acid is able to oxidise zinc, but is unable to oxidise the more active metal aluminium. Explain this observation. **1**

(b) The following diagram is a simplified representation of a soap molecule.

(i) Explain the causes of the hydrophillic nature of the 'head', and the hydrophobic nature of the 'tail' of the soap molecule. **2**

(ii) In solution, soap molecules form micelles with grease. Describe a soap micelle, and account for its stability in a soap solution. **2**

(iii) Describe the difference between a soap and a detergent. **2**

(iv) Nonionic detergents are useful because they are not considerably affected by metal ions in water. Explain this observation, and describe how an anionic detergent forms stable micelles in solution. **2**

(v) Name one use for nonionic detergents. **1**

(c) Consider the industrial manufacture of phosphorus pentachloride given by the reaction;

$$PCl_{3(g)} + Cl_{2(g)} \rightarrow PCl_{5(g)}$$

The following table contains equilibrium and residence time information for the reaction.

Temperature (°C)	Equilibrium Constant	Time required to produce 1 tonne of sulphur dioxide
50	7.5×10^7	5 hours
150	1×10^4	15 minutes
250	100	20 seconds
350	5	0.5 seconds
450	0.1	0.05 seconds

Question 29 continues on page 28

(i) Explain whether you think the reaction is endothermic or exothermic. **1**

(ii) Write down the equilbrium constant for this reaction. **1**

(ii) Qualitatively describe the effect on the equilbrium, and equilbrium constant, of;

(α) increasing temperature **1**

(β) increasing pressure **1**

(iii) Which temperature favours

(α) the largest volume of phosphorus pentachloride produced **1**

(β) the most rapid production of phosphorus pentachloride **1**

(iv) Clint Crop, an engineer in charge of a PCl_5 production facility, wanted to determine the appropriate temperature to operate the reactor. Explain the trade-off Clint is faced with. **2**

(v) What could be done to overcome this trade-off (assuming that cost is not an issue)? **1**

End of Question 29

Question 30 -- Shipwrecks and Salvage (25 marks) **Marks**

(a) Rusting is a huge problem across a number of different industries. A variety of methods can be used to address these problems with new and fancier methods under development.

(i) What are surface alloys? Indicate how surface alloys resist corrosion processes. **3**

(ii) (α) What is galvanised iron? **1**

(β) How does galvanising iron protect it against corrosion? Include any relevant chemical equations in your answer. **3**

(b) There are many different materials that may be found within a ship wreck including metals, textiles, wood and leather, all of which have been subject to the 'salty environment' of the surrounding ocean. A marine archaeologist decides that he wants to restore a leather jacket discovered in an old shipwreck.

(i) Explain how you would remove impregnated salts from the leather jacket. **2**

(ii) Explain what problems might result if the leather jacket were simply 'dried out'. **2**

(iii) After the impregnated salts have been removed from the object suggest a method of further conserving the object. **1**

Question 30 continues on page 30

Question 30. (continued) **Marks**

(c) Minerals in the ocean have a number of different sources including:

- leaching of rainwater from terrestrial environments and

- from the hydrothermal vents in midocean ridges.

(i) Identify two minerals that have their origins in hydrothermal vents. **2**

(ii) Describe the process by which minerals are dissolved from hydrothermal vents. **2**

(d) Faraday was an eminent and ingenious scientist who contributed much to our understanding of electron transfer reactions.

(i) Describe Faraday's contribution to our understanding of redox reactions. **3**

(ii) Describe how Galvani's interaction with frogs led to his contribution to our understanding of redox reactions. **2**

(e) Potassium dichromate is an extremely powerful oxidising agent. When a 5 gram mass of nickel is placed in a solution of acidified potassium dichromate the nickel was observed to dissolve.

(i) Account for this observation by writing half equations for the reaction which took place. **2**

(ii) Determine the number of moles of dichromate ions that must have reacted to dissolve all of the nickel. **2**

End of Question 30

Question 31 -- Biochemistry of Movement (25 marks) **Marks**

(a) Compare and contrast the complete oxidation of palmitic acid and glucose to carbon dioxide and water. In your answer, include **10**

- the pathways by which metabolism occurs;
- the site of metabolism;
- a brief discussion of the approximate amount of energy produced in each case.

(b) Briefly discuss the sliding filament theory of muscle contraction. Include in your answer the role of ATP in this process and name the contractile components in muscle. **4**

(c) A student conducted an experiment to test the effect of temperature on the activity of an enzyme. He selected catalase, which is an enzyme found in chicken liver tissue, and catalyses the decomposition of hydrogen peroxide into water and oxygen gas. Using fresh chicken liver which had been treated as given below, he set up four test tubes in the dark:

- Test tube #1 contained 10mL of hydrogen peroxide.
- Test tube #2 contained 10mL of hydrogen peroxide plus a 1 g piece of chicken liver which had been stored at 4°C for 20 minutes.
- Test tube #3 contained 10 mL of hydrogen peroxide, plus a 1 g piece of chicken liver which had been heated a water both at 37°C for 20 minutes.
- Test tube #4 contained 10 mL of hydrogen peroxide plus a 1 g piece of chicken liver which had been heated in a water bath at 70°C for 20 minutes, and then cooled back to 37°C before it was added.

(a) What is produced in Test tube #1?

(b) Explain why you would expect test tube #3 to be more reactive than test tube #2.

(c) Test tube #4 showed no reaction. Explain.

Question 31 continues on page 32

Question 31. (continued) **Marks**

(d) The major purpose of oxidising fuels is to produce "ATP". Briefly explain what ATP is and its role within the body. **2**

(e) (i) What is the difference between the primary, secondary and tertiary structures of proteins? **3**

(ii) Discuss the types of interactions which are present in the tertiary structure of a protein. **3**

End of Question 31

Question 32 -- Chemistry of Art (25 marks) **Marks**

(a) Materials may be coloured using a number of basic methods. Using the knowledge you have gained in your studies, briefly outline at least two ways materials may be coloured. **3**

(b) **Describe** the experiment you performed to identify the flame colour of the following ions. **6**

Na^+, K^+, Ba^{2+}, Sr^{2+}, and Cu^{2+}

Your answer should include a description of the method, the flame colour of the ions, and any safety precautions.

Explain the origin of the flame colour.

(c) Cobalt occurs in the minerals cobaltite, smaltite, and erythrite, and is often associated with nickel, silver, lead, copper, and iron ores, from which it is most frequently obtained as a by-product. It is also present in meteorites.

The salts have been used for centuries to produce brilliant and permanent blue colours in porcelain, glass, pottery, tiles, and enamels. It is the principal ingredient in Sevre's and Thenard's blue. A solution of the chloride is used as a sympathetic ink.

(i) Write the electron configuration of the cobalt(II) ion in sp notation. **1**

(ii) Draw the Lewis electron dot formula for one complex of cobalt. Identify the colour of the complex ion you have drawn. **3**

Question 32 continues on page 34

Question 32. (continued) **Marks**

(d) In your studies you have processed information to identify and analyse the chemical composition of a range of pigments. Select three pigments you have studied. For each identify **3**

- the chemical composition;
- the source of the pigment;
- the use(s) of the pigment.

(e) Outline the use of infra-red and ultra-violet light in the analysis and identification of pigments and their chemical composition. **3**

(f) Does ammonia function as a Lewis acid, Lewis base or neither when forming a complex ion with copper (II) ion? Using appropriate diagrams and equations, explain your answer. **3**

(g) The discoveries of emission and absorption spectra are examples of important developments in the history of chemistry. **2**

Assess the impact of the discoveries on the development of one analytic instrument used by forensic chemists in the study of pigments and paints in art works.

End of Question 32

Question 33 -- Forensic Chemistry (25 marks) **Marks**

(a) What of the biggest distinctions jobs of a chemist is to be able to classify substances into different classes: for example inorganic and organic compounds or acids and bases.

(i) Suggest a simple method which you could use to determine if a compound was more likely to be inorganic or organic. **2**

(ii) How might you determine whether a solid was an acid or a base if you were told that the solid was insoluble. **2**

(iii) How might you quickly distinguish between a carbohydrate and a protein? **2**

(b) DNA profiling is an amazing advancement which allows the accurate identification of human tissue samples.

(i) Describe briefly the steps undertaken to obtain a DNA profile. **4**

(ii) Briefly explain by referring to the part of the molecule examined by DNA profiling, how a DNA profile is unique to each individual. **2**

(iii) Analyse the impact that DNA profiling may have on modern forensic investigations. Include a specific example in your answer. **2**

Question 33 continues on page 36

Question 33. (continued) **Marks**

(c) Nectar from flowers contains sucrose. When the nectar is tested with Benedict's reagent, a negative result is obtained. Bees have an enzyme which causes the inversion of sucrose, so that honey gives a positive result.

(i) What does Benedict's reagent test for? **2**

(ii) What is observed with a positive result? **1**

(iii) What other test could be used in place of the Benedict's test and what occurs with a positive result ? **2**

(d). There are many different types of proteins including structural proteins and globular proteins.

(i) Identify 2 different proteins from each of these classes. **2**

(ii) How might a forensic investigator distinguish between different types of structural proteins? **2**

(e) Distinguishing between different organic compounds is one of the fundamental components of investigative chemistry. Describe a test (other than testing pH), which you could perform which would enable you to distinguish between propanol and propanoic acid. **2**

End of Question 33

DATA SHEET

Numerical constants

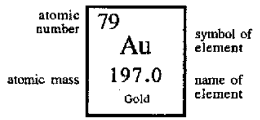
Avagadro's constant, N	6.022×10^{23} mol^{-1}	Gas constant, R	8.314 J K^{-1}mol^{-1}
Boltzmann's constant, k	1.381×10^{-23} J K^{-1}	Mass of electron, m_e	0.0821 L atm K^{-1}mol^{-1}
Elementary charge, e	1.602×10^{-19} C^{-1}	Mass of neutron, m_n	9.109×10^{-31} kg
Faraday's constant, F	96 490 C mol^{-1}	Mass of proton, m_p	1.675×10^{-27} kg
Volume of 1 mole ideal gas at 101.3 kPa (1 atm):			1.673×10^{-27} kg
at 0°C (273 K)	22.41 L		
at 25°C (298 K)	24.47 L		

Standard Electrode Potentials

$K^+ + e^-$	$\rightleftarrows$	$K_{(s)}$	−2.92 V
$Ba^{2+} + 2e^-$	$\rightleftarrows$	$Ba_{(s)}$	−2.90 V
$Ca^{2+} + 2e^-$	$\rightleftarrows$	$Ca_{(s)}$	−2.87 V
$Na^+ + e^-$	$\rightleftarrows$	$Na_{(s)}$	−2.71 V
$Mg^{2+} + 2e^-$	$\rightleftarrows$	$Mg_{(s)}$	−2.36 V
$Al(OH)4 + 3e^-$	$\rightleftarrows$	$Al^+ + 4OH^-$	−2.33 V
$Al^{3+} + 3e^-$	$\rightleftarrows$	$Al_{(s)}$	−1.66 V
$H_2O + e^-$	$\rightleftarrows$	$\frac{1}{2}H_{2(g)} + OH^-$	−0.83 V
$Zn^{2+} + 2e^-$	$\rightleftarrows$	$Zn_{(s)}$	−0.76 V
$Fe^{2+} + 2e^-$	$\rightleftarrows$	$Fe_{(s)}$	−0.41 V
$CuO + 2e^- + H_2O$	$\rightleftarrows$	$Cu_{(s)} + 2OH^-$	−0.36 V
$Ni^{2+} + 2e^-$	$\rightleftarrows$	$Ni_{(s)}$	−0.23 V
$Sn^{2+} + 2e^-$	$\rightleftarrows$	$Sn_{(s)}$	−0.14 V
$CO_{2(g)} + 4H^+ + 4e^-$	$\rightleftarrows$	$HCHO + H_2O$	−0.07 V
$CO_{2(g)} + 4H^+ + 4e^-$	$\rightleftarrows$	$\frac{1}{6}C_6H_{12}O_6$ (glucose) $+ H_2O$	−0.01 V
$H^+ + e^-$	$\rightleftarrows$	$\frac{1}{2}H_{2(g)}$	0.00 V
$CO_{2(g)} + 6H^+ + 6e^-$	$\rightleftarrows$	$CH_3OH + H_2O$	0.03 V
$CO_{2(g)} + 8H^+ + 8e^-$	$\rightleftarrows$	$CH_{4(g)} + 2H_2O$	0.17 V
$AgCl(s) + e^-$	$\rightleftarrows$	$Ag(s) + Cl^-$	0.22V
$HCOH + 2H^+ + 2e^-$	$\rightleftarrows$	CH_3OH	0.24 V
$Cu^{2+} + 2e^-$	$\rightleftarrows$	$Cu_{(s)}$	0.35 V
$\frac{1}{2}O_{2(g)} + H_2O + 2e^-$	$\rightleftarrows$	$2OH^-$	0.40 V
$HCOH + 4H^+ + 4e^-$	$\rightleftarrows$	$CH_{4(g)} + H_2O$	0.41 V
$Cu^+ + e^-$	$\rightleftarrows$	$Cu_{(s)}$	0.52 V
$\frac{1}{2}I_{2(s)} + e^-$	$\rightleftarrows$	I^-	0.54 V
$\frac{1}{2}I_{2(aq)} + e^-$	$\rightleftarrows$	I^-	0.62 V
$Ag^+ + e^-$	$\rightleftarrows$	$Ag_{(s)}$	0.80 V
$NO_3^- + 4H^+ + 3e^-$	$\rightleftarrows$	$NO_{(g)} + 2H_2O$	0.96 V
$\frac{1}{2}Br_{2(aq)} + e^-$	$\rightleftarrows$	Br^-	1.09 V
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$	$\rightleftarrows$	H_2O	1.23 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftarrows$	$Cr^{3+} + \frac{7}{2}H_2O$	1.33 V
$\frac{1}{2}Cl_{2(g)} + e^-$	$\rightleftarrows$	Cl^-	1.36 V

PERIODIC TABLE OF THE ELEMENTS

Key



																	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 32.06 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 47.90 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 58.71 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.59 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 Cesium	56 Ba 137.3 Barium	57 La 138.9 Lanthanum	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 — Polonium	85 At — Astatine	86 Rn — Radon
87 Fr — Francium	88 Ra — Radium	89 Ac — Actinium	104 — Element 104	105 — Element 105	106 — Element 106												

58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm — 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
90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np 237.0 Neptunium	94 Pu — Plutonium	95 Am — Americium	96 Cm — Curium	97 Bk — Berkelium	98 Cf — Californium	99 Es — Einsteinium	100 Fm — Fermium	101 Md — Mendelevium	102 No — Nobelium	103 Lr — Lawrencium