TASMANIAN QUALIFICATIONS AUTHORITY

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Tasmanian Certificate of Education

CHEMISTRY

Senior Secondary Level 3

Subject Code: CHM315109

Sample Examination

2009

Part 1

Time: approximately 45 minutes

On the basis of your performance in this examination, the examiners will provide a result on the following criterion taken from the syllabus statement:

Criterion 5 Demonstrate an understanding of the fundamental principles and theories of electrochemistry.

Criterion	Mark
5	/40

Pages: 12
Questions: 9

CANDIDATE INSTRUCTIONS

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NOTE: 1 litre (L) = 1000 millilitres (mL) = 1 dm^3 = 1000 cm^3.

All written responses must be in English.

For Marker Use Only

Question 1

(a) List the oxidation states of bromine in the following compounds: (2 marks)

Br_2O ..... BrO_2 .....

HBr ..... Br_2 .....

(b) Is the following equation an example of oxidation-reduction? Give reasons. (2 marks)

$$SF_{4(g)} + H_2O_{(g)} \rightarrow SOF_{2(g)} + 2HF_{(g)}$$

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Question 2

This question assesses Criterion 5.

In acidic solution the perchlorate ion, ClO_4^-, will oxidise the sulfite ion, SO_3^{2-}, to sulfate, SO_4^{2-}, and is reduced to chlorine gas, Cl_2.

Write the two half equations, and hence the overall equation for this reaction. (4 marks)

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For Marker Use Only

Question 3

A typical Hall-Heroult cell used for the electrolytic extraction of aluminium from molten alumina, $Al_2O_3(l)$, operates at 5.00 volts with a current of 150 000 amperes.

(a) Write the half equation for the reduction of the aluminium ion in the alumina.

(1 mark)

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(b) Determine the mass of aluminium produced by such a cell over a 24.0 hour period.

(3 marks)

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Question 4

For Marker Use Only

Calcium metal is produced by the electrolysis of molten calcium chloride, $CaCl_2$, using inert electrodes.

(a) Write an equation showing the products at: (2 marks)

(i) the anode:

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(ii) the cathode:

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(b) If a dilute aqueous solution of calcium chloride were electrolysed with inert electrodes, indicate (using an equation) the products expected at each electrode. (2 marks)

(i) the anode:

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(ii) the cathode:

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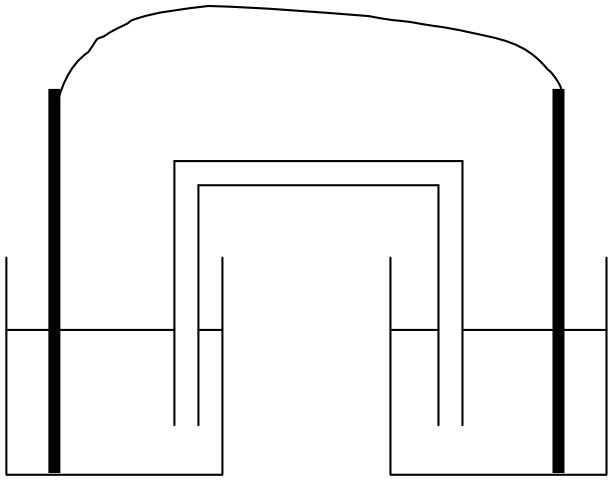
Question 5

For Marker Use Only

Complete the diagram below to illustrate the standard state electrochemical cell represented by:

$$Cd_{(s)}\left|Cd^{2+}{}_{(aq)}\right\|Cr_2O_7{}^{2-}{}_{(aq)}\left|Cr^{3+}{}_{(aq)}\right|C_{(s)}$$

(a) On the diagram label the electrodes, solutions, anode and anode reaction, cathode and cathode reaction, salt bridge and show the direction of electron flow in the external circuit, and the ion flow through the salt bridge. (4 marks)



(b) Calculate the maximum net E^o for this cell. (1 mark)

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(c) Outline the main requirements for a salt bridge chemical and suggest a suitable chemical for the salt bridge in this cell. (2 marks)

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Question 6

For Marker Use Only

In an experiment to determine where germanium and titanium would be placed in the electrochemical series ('Standard Reduction Potential' table) the following results were obtained. (Standard state conditions were used.)

- Germanium, Ge, reacted slowly with copper(II) ions in solution to produce germanium(II) ions and copper metal.
- Germanium did not react with dilute acids or with solutions of tin(II) ions.
- Aluminium, with the oxide layer removed, reacted with a solution of titanium(II) ions to produce aluminium ions and titanium metal.
- Manganese metal did not react with a solution of titanium(II) ions.

(a) Where would $Ge^{2+}_{(aq)} + 2e^- \rightarrow Ge_{(s)}$ be placed in the series? (1 mark)

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(b) Where would $Ti^{2+}_{(aq)} + 2e^- \rightarrow Ti_{(s)}$ be placed in the series? (1 mark)

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(c) Predict whether a reaction would occur between titanium metal and a 1.00 mol L^{-1} solution of hydrochloric acid. Explain your answer. (2 marks)

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For Marker Use Only

Question 7

Predict whether a reaction will occur spontaneously when an iron nail is placed in an aqueous solution of tin(II) chloride. Assume standard state conditions.

If a reaction will occur spontaneously, write the equation for the reaction. However, if no reaction would occur, give chemical reasons for this. (2 marks)

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Question 8

One of the earliest examples of marine corrosion occurred in the eighteenth century on the British Navy battleship H.M.S. Alarm. The vessel had its wooden hull covered by copper sheeting which was fastened by iron nails. Not surprisingly the iron nails corroded rapidly and some copper sheeting fell off the hull.

(a) Explain, using the principles of electrochemistry, why the **rapid** corrosion took place. (4 marks)

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Question 8 continues opposite.

Question 8 (continued)

For Marker Use Only

Predict whether a reaction will occur spontaneously when an iron nail is placed in an aqueous solution of tin(II) chloride. Assume standard state conditions.

(b) If a reaction will occur spontaneously, write the equation for the reaction. However, if no reaction would occur, give chemical reasons for this. (2 marks)

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Question 9

For Marker Use Only

An underground steel tank (assumed to be made of Fe) is used for the storage of diesel fuel. To prevent corrosion of the tank in the moist ground, an impressed current ('Applied EMF') is used. One terminal of a 12 volt battery (above ground) is connected to the tank by an insulated wire and the other battery terminal is connected by an insulated wire to an inert metal rod electrode in the ground near but not touching the tank.

(a) Draw a labelled diagram showing the steel tank, the inert electrode, the 12 V supply and the direction of electron flow in the connecting wires. Label the anode and cathode of the 12 V battery and the anode and cathode sites underground.

(3 marks)

(b) Give the half-equation for the redox reaction occurring:

(2 marks)

(i) on the surface of the steel tank.

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(ii) on the surface of the inert metal electrode.

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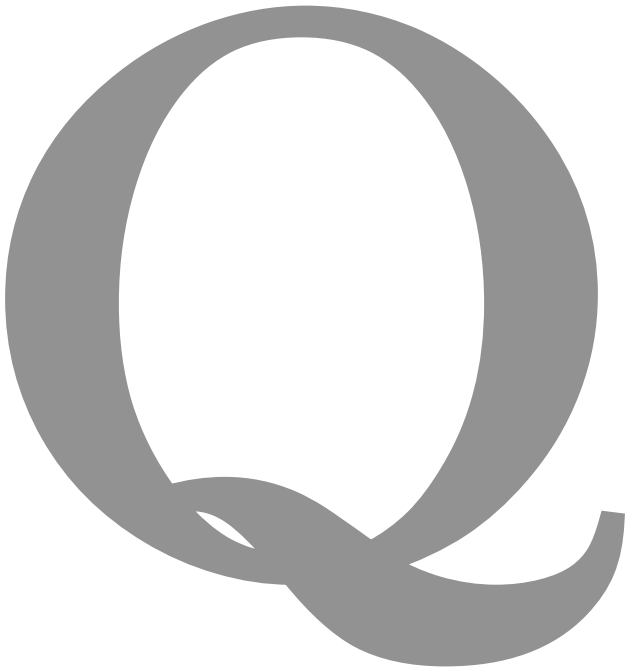

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Tasmanian Certificate of Education

CHEMISTRY

Senior Secondary Level 3

Subject Code: CHM315109

Sample Examination

2009

Part 2

Time: approximately 45 minutes

On the basis of your performance in this examination, the examiners will provide a result on the following criterion taken from the syllabus statement:

Criterion 6 Demonstrate knowledge and understanding of the principles and theories of thermochemistry, reaction kinetics and equilibrium.

Criterion	Mark
6	/40

Pages: 12
Questions: 9

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For Marker Use Only

Question 10

The rates of most chemical reactions decrease over time. For example, the reaction between hydrogen ions and carbonate ions may be quite rapid when they are first mixed (producing carbon dioxide gas), but it is observed that the measured rate of gas evolution reduces as the reaction proceeds. Explain why this happens. (2 marks)

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Question 11

Some ***exothermic*** reactions must be carried out with great care since their reaction rates can accelerate so quickly they become dangerous. Explain, at the molecular level, what may cause this effect. (3 marks)

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For Marker Use Only

Question 12

The bond energy of a chemical bond is the energy required to overcome the forces operating between atoms which hold them together.

Some bond energies are listed in the table below:

Bond Type	Bond Energy (kJ mol^{-1})
C – H	435
C – C	347
O = O	498
C = O	805
O – H	464

The reaction for the combustion of propane (the gas used in most bunsen burners) is given by the equation:

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$$

Use the information in the table (and your knowledge of chemical structures) to calculate a value for the amount of energy released if exactly one mole of propane reacts with sufficient oxygen. What is the value of the enthalpy change $(\Delta \mathbf{H})$ for the reaction? Clearly show your method of calculation. (4 marks)

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For Marker Use Only

Question 13

The heat of combustion of ethanol is $\Delta H = -1371$ kJ mol^{-1}, i.e.

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g) \qquad \Delta H = -1371 \text{ kJ mol}^{-1}$$

(a) Given that 3.00 L of water is to be heated from 25.0ºC to 100.0ºC using the combustion of ethanol as a heat source, show that the mass of ethanol required to be burnt is 31.6 g. (Assume 100% thermal efficiency i.e. no heat losses occur to the surroundings.)

(3 marks)

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(b) If in reality, the heating process was only 35.0% thermally efficient, what mass of ethanol fuel would now be required to carry out the same heating porcess as in (a) above? (1 mark)

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For Marker Use Only

Question 14

A student is presented with two aqueous solutions of monoprotic acids HA(aq) and HB(aq) HB(aq) both of which have concentrations of 0.100 mol L^{-1}. One of the acids is known to be known to be weak and one is a strong acid.

The student attempts to identify the weak acid by titrating 20.0 mL samples of each acid acid against a known solution of sodium hydroxide, assuming the weaker acid will require a require a smaller volume of base for neutralisation.

The student finds to their surprise that both acids require exactly the same volume of base for of base for neutralisation. Explain why the method was not successful in identifying the weak identifying the weak acid from the strong acid. (4 marks)

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Question 15

For Marker Use Only

Zinc metal and dilute hydrochloric acid solution react according to the equation:

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow Zn^{2+}(aq) + 2Cl^{-}(aq) + H_{2(g)}$$

The reaction starts slowly at room temperatures and gradually speeds up. The beaker containing the reaction becomes warmer as the reaction proceeds.

(a) Is the reaction exothermic or endothermic? Give a reason. (2 marks)

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(b) What is the relative size of the activation energy? Explain. (2 marks)

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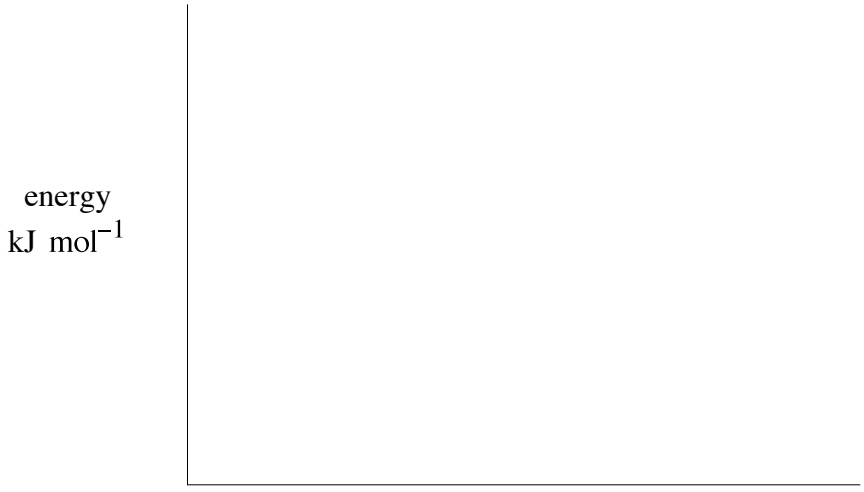
(c) On the axes below draw an energy diagram for this reaction indicating reactants, products, ΔH and activation energy. (2 marks)



(d) A piece of copper wire wound around the zinc catalyses the reaction. Show the effect of the catalyst on the graph above with a dotted line. (1 mark)

Question 16

For Marker Use Only

The reaction between calcium and water is represented by:

$$Ca_{(s)} + 2H_2O_{(\ell)} \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$$

A student conducts an experiment and has three beakers containing the following:

- Beaker A: 2.00 g lump of calcium, 2.00 L of water at 15ºC temperature;
- Beaker B: 2.00 g lump of calcium, 2.00 L of water at 25ºC temperature;
- Beaker C: 2.00 g of small calcium pieces, 2.00 L of water at 25ºC temperature.

(a) Which beaker will have the fastest reaction rate? (1 mark)

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(b) Give reasons in terms of Collision Theory for your answer in (a). (3 marks)

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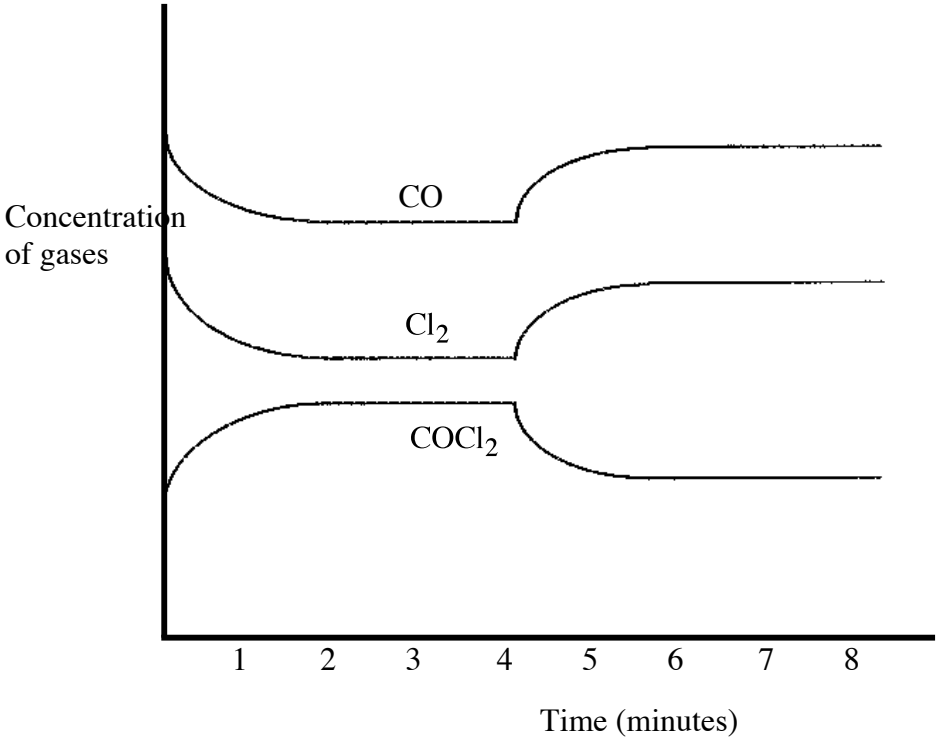
Question 17

For Marker Use Only

Carbonyl chloride gas, $COCl_2$ is prepared according to the following reversible reaction:

$$CO_{(g)} + Cl_{2(g)} \rightleftharpoons COCl_{2(g)}$$

A mixture containing these three gases is introduced into a closed system in the presence of a charcoal catalyst. The following graph shows how the concentration of these gases varies with time.



(a) Describe the system three minutes after mixing. (1 mark)

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(b) Four minutes after mixing, the temperature was increased by 25ºC. From the system's response shown on the graph above, deduce whether the reaction as written is endothermic or exothermic. Explain. (3 marks)

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Question 17 continues over the page.

Question 17 (continued)

For Marker Use Only

(c) Write an expression for the equilibrium constant of this reaction. (1 mark)

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(d) 0.100 mole of $COCl_{2(g)}$ is put into a 2.00 L closed vessel and allowed to come to equilibrium at 25ºC. When equilibrium reached the $COCl_{2(g)}$ concentration is measured as 0.0447 mol L^{-1}.

Calculate the equilibrium constant at a temperature of 25ºC. (4 marks)

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Question 18

For Marker Use Only

Calculate ΔH for the oxidation of ammonia, NH_3, to nitrogen dioxide, NO_2.

$$4NH_{3(g)} + 7O_{2(g)} \rightarrow 4NO_{2(g)} + 6H_2O_{(g)}$$

Use the following data: (3 marks)

$$N_{2(g)} + 3H_{2(g)} \longrightarrow 2NH_{3(g)} \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

$$N_{2(g)} + 2O_{2(g)} \longrightarrow 2NO_{2(g)} \qquad \Delta H = -68 \text{ kJ mol}^{-1}$$

$$2H_{2(g)} + O_{2(g)} \longrightarrow 2H_2O_{(g)} \qquad \Delta H = -484 \text{ kJ mol}^{-1}$$

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CHEMISTRY

Senior Secondary Level 3

Subject Code: CHM315109

Sample Examination

2009

Part 3

Time: approximately 45 minutes

On the basis of your performance in this examination, the examiners will provide a result on the following criterion taken from the syllabus statement:

Criterion 7 Demonstrate knowledge and understanding of the properties and reactions of organic and inorganic matter.

Criterion	Mark
7	/40

Pages: 12
Questions: 9

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Question 19

(a) Explain why the element potassium has the ground state electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$, rather than $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$. (1 mark)

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(b) Explain how atoms of potassium can be changed to have the excited electron configuration of $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$. (2 marks)

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Question 20

(a) Describe and explain the trend in atomic radii of the atoms Na, Mg, Al and Si. (2 marks)

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(b) Describe the trend in the atomic radii of the atoms F, Cl, and Br. Explain how this affects their ease of conversion to the ions F^-, Cl^-, and Br^-. (3 marks)

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For Marker Use Only

Question 21

The electronic configurations of three elements are.

Element	Electron configuration
A	$1s^2 2s^2 2p^6 3s^2 3p^1$
B	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^5$
C	$1s^2 2s^2 2p^6 3s^2 3p^3$

(a) A and B form a compound. What is its formula in terms of A and B? (1 mark)

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(b) B and C also form a compound. What is its formula in terms of B and C and describe the bonding present in a solid sample of this compound. (2 marks)

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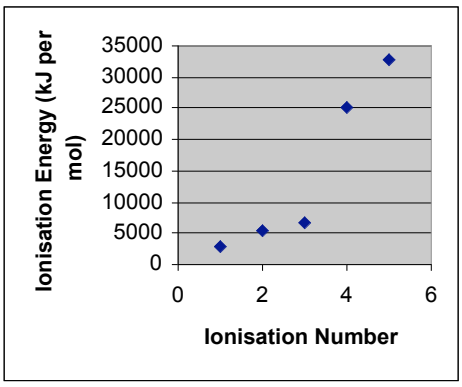
Question 22

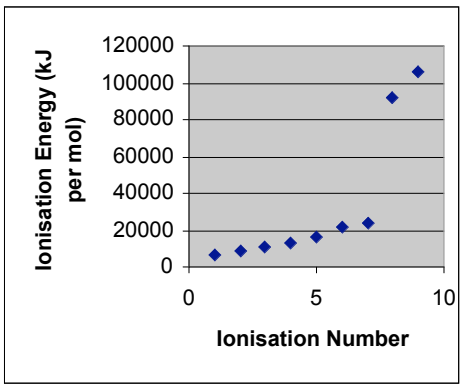
For Marker Use Only

The successive ionisation energies of boron and fluorine are plotted in the following graphs:

Boron



Fluorine



(a) Write down the electron configuration for each element. (1 mark)

Boron: .....

Fluorine: .....

(b) In both instances above, why is there such a large increase in the ionisation energy required to remove the last two electrons? (2 marks)

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(c) Using the information on the graphs, explain how the position of the two elements in the Periodic Table can be determined. (2 marks)

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For Marker Use Only

Question 23

The table below lists the oxides of the elements of the third period.

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Oxide	Na_2O	MgO	Al_2O_3	SiO_2	P_4O_{10}	SO_3	Cl_2O_7	

(a) Explain the trend in reactivity of the elements across the period. (3 marks)

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(b) How does the acid/base property of the oxides change across the period? (1 mark)

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Question 24

For Marker Use Only

(a) Write a **structural** formula equation for the reaction of ethanoic (acetic) acid (CH_3COOH) and methanol in the presence of concentrated sulfuric acid. (2 marks)

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(b) Draw the structural formula of the compound 2-methylpropan-1-ol and the compound formed when 2-methylpropan-1-ol is oxidised with **excess** acidified hydrogen peroxide. (2 marks)

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(c) Briefly describe a simple laboratory test that could be used to distinguish between ethanol and ethanal. What observations would you expect? (2 marks)

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(d) An addition polymer can be formed using 3-fluoroprop-1-ene as the monomer, using a suitable catalyst. Draw 3 units of the polymer chain. (2 marks)

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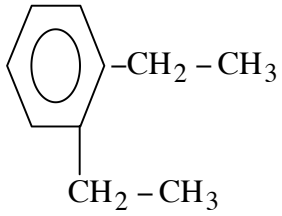
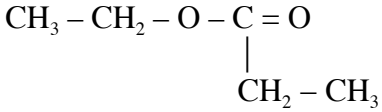
Question 25

For Marker Use Only

Complete the following table: (4 marks)

Name	Structural formula	
		Functional group present:
		Functional group present: Secondary alcohol Heaviest mass seen in mass spectrum = 60 amu
2,5,-dichloro-2-methylheptane		Empirical Formula:
		Functional group present:

For Marker Use Only

Question 26

Elemental analysis of two organic liquids indicated they were composed of carbon, hydrogen and oxygen. Mass spectral analysis showed that they both have the same molecular mass of 58.0. Infrared spectroscopic evidence shows that both compounds contain one $C=O$ bond and no other oxygen atoms.

(a) What are the structural formulae and names of the two compounds? (2 marks)

Compound 1: Name

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Compound 2: Name

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(b) Explain how you would distinguish between the two experimentally, using acidified potassium permanganate solution. Include relevant equations. (2 marks)

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For Marker Use Only

Question 27

Boiling points of some organic compounds are listed in the table below.

Compound	Propan-1-ol	Propanal	Propanone	Propanoic acid
Boiling points, °C	92.7	47.9	56.1	140.8

(a) Why are the boiling points of propan-1-ol and propanoic acid higher than the boiling points of propanal and propanone? Explain carefully. (2 marks)

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(b) Which of these four compounds would be expected to be soluble in water? Give reasons. (2 marks)

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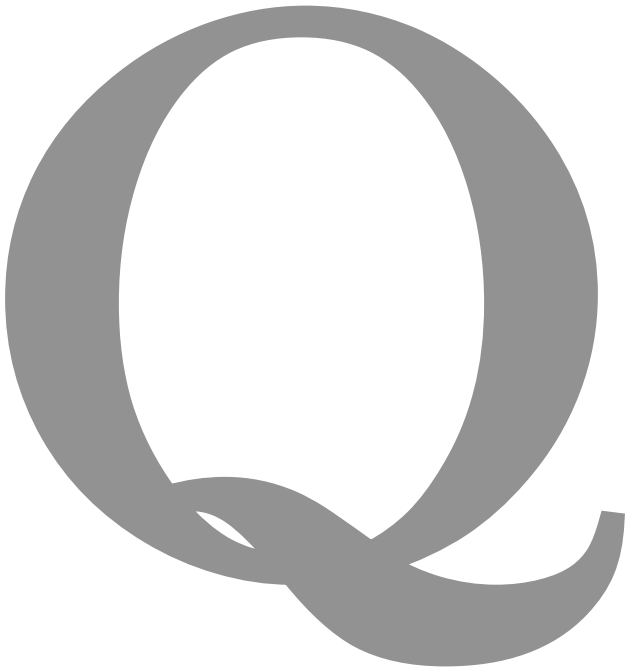

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Subject Code: CHM315109

Sample Examination

2009

Part 4

Time: approximately 45 minutes

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Criterion 8 Apply logical processes to solve quantitative chemical problems.

Criterion	Mark
8	/40

Pages: 12
Questions: 9

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For Marker Use Only

Question 28

A polythene weather balloon is released at sea level at an atmospheric pressure of 104 kPa and a temperature of 25°C. Under these conditions its volume is 2250 L. The balloon then ascends to an altitude of 10 000m where the temperature is –55°C and the atmospheric pressure has dropped to 24.5 kPa.

Calculate the volume of the balloon at this altitude if it is able to expand freely. (3 marks)

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Question 29

Calculate the pH of a mixture of 150 mL of a 0.0150 mol L^{-1} sulfuric acid solution, $H_2SO_{4(aq)}$ and 50.0 mL of a 0.0300 mol L^{-1} potassium hydroxide solution, $KOH_{(aq)}$.
(Assume full dissociation of the sulfuric acid.) (4 marks)

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For Marker Use Only

Question 30

A volatile organic solvent, C_3H_6O, becomes explosive at gaseous concentrations greater than 1.195 g L^{-1} in air at 39.5°C. What is the partial pressure of the C_3H_6O vapour at this limit? Express your answer in units of kPa. (3 marks)

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Question 31

Life support systems in the Russian manned 'Soyuz' space flights involve air purification units that absorb carbon dioxide by using sodium superoxide NaO_2, while regenerating oxygen.

$$4NaO_{2(s)} + 2CO_{2(g)} \rightarrow 2Na_2CO_{3(s)} + 3O_{2(g)}$$

100.0 g of sodium superoxide is reacted with 42.5 g of carbon dioxide:

(a) By determining the limiting reactant, calculate the maximum mass of oxygen that can be obtained? (4 marks)

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(b) What mass of the reagent in excess is left over after the reaction is complete? (2 marks)

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Question 32

For Marker Use Only

The amount of oxygen in a container was determined by using it to oxidise acidified $Fe^{2+}_{(aq)}$ ion in the presence of a cobalt catalyst.

$$4Fe^{2+}_{(aq)} + O_{2(g)} + 4H^{+}_{(aq)} \rightarrow 4Fe^{3+}_{(aq)} + 2H_2O_{(\ell)}$$

324 mL of a 0.200 mol L^{-1} solution of the acidified $Fe^{2+}_{(aq)}$ was required to completely react with the oxygen in the tank.

(a) Calculate the mass of oxygen in the tank. (3 marks)

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(b) What is the minimum volume of 2.00 mol L^{-1} sulfuric acid solution needed for the reaction? (1 mark)

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(c) What volume of 12.0 mol L^{-1} sulfuric acid would be needed to make up the solution required in (b)? (1 mark)

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Question 33

For Marker Use Only

Calculate the mass of the precipitate formed when 125 mL of 0.250 mol L^{-1} sodium iodide solution is added to 150 mL of 0.200 mol L^{-1} lead(II) nitrate solution. (4 marks)

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Question 34

For Marker Use Only

A chemist is required to determine the percentage of nickel in an alloy which contains only iron and nickel. A sample of the alloy is finely ground up, and a sample of mass 11.60 g is added to a dilute sulfuric acid solution until the evolution of hydrogen gas ceases and there is no solid metal remaining. The solution is diluted to a total volume of 100.0 mL in a volumetric flask.

It can be seen from the table in the Information Sheet that the resulting solution contains Fe^{2+} ions and Ni^{2+} ions. The Fe^{2+} can be further oxidised to Fe^{3+} by titration against a solution of acidified dichromate ions ($Cr_2O_7^{2-}/H^+$). (The nickel is now in its maximum oxidation state and will not be further oxidised by the acidified potassium dichromate solution).

The equation for the titration reaction is therefore:

$$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+ \rightarrow 6Fe^{3+} + 2Cr^{3+} + 7H_2O$$

(a) To make an approximately 0.2 mol L^{-1} dichromate solution 11.32 g of potassium dichromate ($K_2Cr_2O_7$) crystals are dissolved in dilute sulfuric acid and the total volume made up to 200.0 mL in a volumetric flask.

Calculate the actual concentration of the dichromate ions in the resulting solution.

(2 marks)

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Question 34 continues over the page.

Question 34 (continued)

For Marker Use Only

(b) The acidified dichromate ion solution was placed in a burette and titrated against 20.00 mL samples of the Fe^{2+}/Ni^{2+} solution taken from a pipette. The average volume of the acidified dichromate solution from the burette was 20.80 mL.

Use this information to determine the concentration of Fe^{2+} in the original solution and hence the percentage by mass of iron in the alloy? (5 marks)

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For Marker Use Only

Question 35

A saturated aqueous solution of calcium hydroxide ($Ca(OH)_2$) is found to have a pH of 12.4 at standard laboratory temperature.

(a) What is the hydroxide ion concentration in the solution in mol L^{-1}? (2 marks)

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(b) Calculate the solubility of calcium hydroxide at this temperature in units of g L^{-1} (grams per litre) if the calcium hydroxide is present in the solution in the form of calcium ions and hydroxide ions only. (2 marks)

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For Marker Use Only

Question 36

The K_a for ethanoic acid, CH_3COOH, is 1.80×10^{-5}. Calculate the pH of a 0.150 mol L^{-1} aqueous solution of ethanoic acid. (4 marks)

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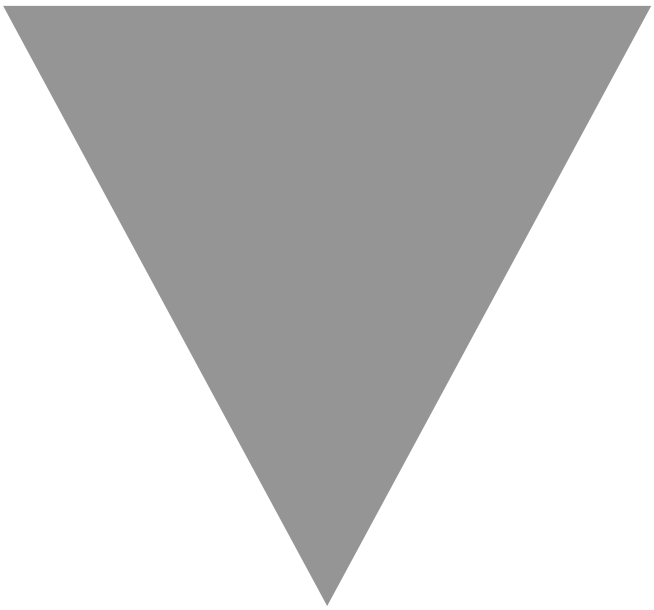

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