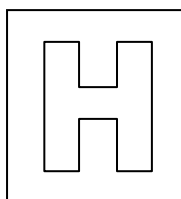


Class Adm No

Candidate Name: _____

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2017 Preliminary Examination II

Pre-University 2

H1 CHEMISTRY

8872/01

Paper 1 Multiple Choice

19th Sep 2017

50 minutes

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write in soft pencil.

Do not use staples, paper clips, glue or correction fluid.

Write your name, class and admission number in the spaces provided at the top of this page and on the Multiple Choice Answer Sheet provided.

There are thirty questions on this paper. Answer **ALL** questions. For each question there are four possible answers **A, B, C** and **D**.

Choose the **one** you consider correct and record your choice in **soft pencil** on the Multiple Choice Answer Sheet provided.

Read the instructions on the Multiple Choice Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this question paper.

The use of an approved scientific calculator is expected, where appropriate.

| | |
|--------------------|--|
| FOR EXAMINER'S USE | |
| TOTAL (30 marks) | |

Section A

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

- 1 A sample of a rare ore containing iron and molybdenum was investigated. The composition of the sample is given in the table below.

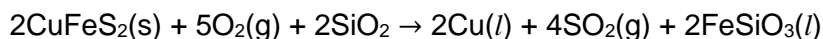
| | | | | |
|--------------------|----|----|----|----|
| mass number | 55 | 56 | 95 | 96 |
| % abundance | 5 | 54 | 36 | 5 |

What is the A_r of Fe in this sample of Elinvar?

- A** 55.8 **B** 55.9 **C** 72.0 **D** 75.5
- 2 Perfluoroacetic acid is a structural analogue of ethanoic acid and is a stronger acid than ethanoic acid. The percentage composition by mass of perfluoroacetic acid is given as: C, 21.1%; H, 0.90%; O, 28.1%; F, 49.9%.

What is the empirical formula of perfluoroacetic acid?

- A** CHO_2F_2
B $\text{C}_2\text{H}_2\text{OF}$
C $\text{C}_2\text{HO}_2\text{F}_2$
D $\text{C}_2\text{HO}_2\text{F}_3$
- 3 Chalcopyrite is a common copper ore with the chemical formula CuFeS_2 . Copper can be extracted from chalcopyrite through the roasting of the ore and undergoes the following reaction.



What is the mass of chalcopyrite needed to produce 10 g of Cu?

- A** 28.9
B 51.6
C 57.8
D 103

- 4 Use of the Data Booklet is relevant to this question.

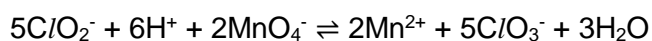
Chloride ions can be oxidised to hypochlorous acid as shown below.



If 2 moles of acidified MnO_4^- were reacted with 1 mole of Cl^- ions, how many moles of hypochlorous acid would be obtained?

- A 1
B 2
C 5
D 10

- 5 What is the change in oxidation number of chlorine and manganese in the following reaction?



| | Chlorine | manganese |
|---|----------|-----------|
| A | 0 | +3 |
| B | +1 | -5 |
| C | +2 | -5 |
| D | +2 | +3 |

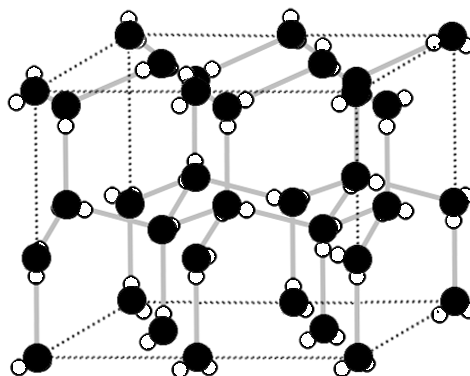
- 6 The first six ionisation energies of an element, A, in kJ mol^{-1} are given below.

947 1798 2735 4837 6043 12310

A forms an oxide. What is the empirical formula of the oxide?

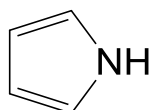
- A AO
B A₂O
C AO₂
D A₂O₃

- 7 The diagram below shows the structure of ice.



Which of the following statements about ice is correct?

- A** The bond angle about oxygen atom is 109.5° .
- B** There are strong covalent bonds between water molecules.
- C** A sample of ice occupies a smaller volume than a sample of water with the same mass.
- D** Ice has a giant covalent lattice.
- 8 Recycling metals are important to many countries. Which of the following statements does **not** explain why recycling is important?
- A** It is energy intensive to extract metals from its ore.
- B** Natural resources are used up during the extraction of metals.
- C** It is expensive to dispose of waste produced in the extraction process.
- D** Recycling increases the consumption of non-renewable resources.
- 9 What is the number of sigma (σ) and pi (π) bonds in this molecule?



pyrrole

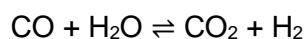
- | | σ | π |
|----------|----------|-------|
| A | 9 | 2 |
| B | 9 | 3 |
| C | 10 | 2 |
| D | 10 | 3 |

10 Which of the following compounds has the least exothermic lattice energy?

- A barium oxide
- B barium sulfide
- C magnesium oxide
- D magnesium sulfide

11 *Use of the Data Booklet is relevant to this question.*

The water-gas shift reaction is used industrially to obtain hydrogen and is shown below.

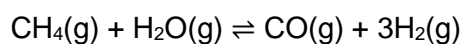


The C≡O bond enthalpy is 1076 kJ mol⁻¹.

What is the enthalpy change for the reaction?

- A +80 kJ mol⁻¹
- B -80 kJ mol⁻¹
- C +360 kJ mol⁻¹
- D -360 kJ mol⁻¹

12 Methane and steam undergo a reaction as shown below.



A mixture containing 4 moles of gas with methane and steam in 1:1 ratio is injected into a 5 dm³ vessel. After some time, 1 mole of water is left.

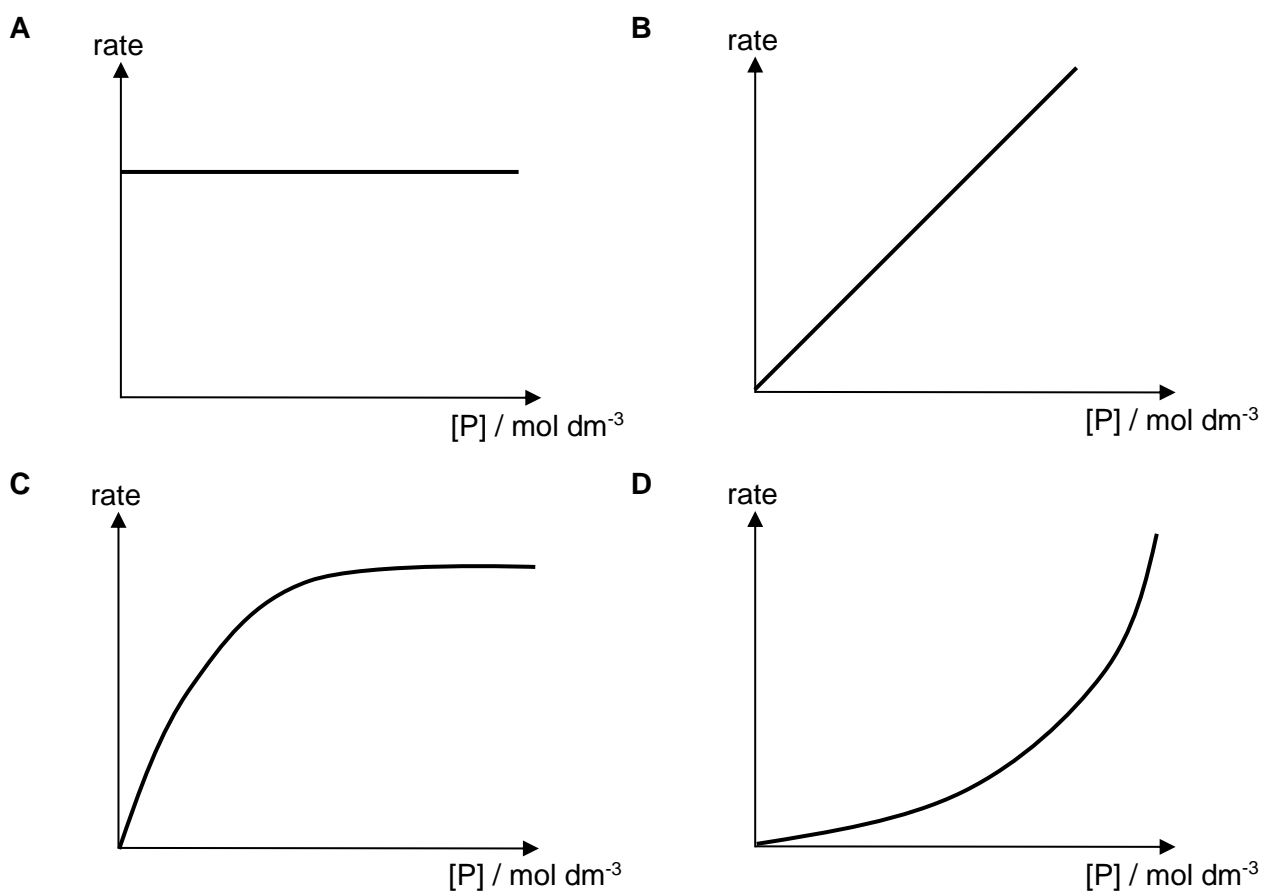
What is the numerical value of the equilibrium constant, K_c , for the reaction?

- A 27
- B 9
- C 1.08
- D 0.04

- 13 A reaction between **P** and **Q** is investigated and the following experimental results were obtained.

| experiment | initial concentration of P / mol dm ⁻³ | initial concentration of Q / mol dm ⁻³ | initial rate / mol dm ⁻³ s ⁻¹ |
|------------|--|--|---|
| 1 | 0.5 | 1.0 | 0.005 |
| 2 | 0.5 | 4.0 | 0.020 |
| 3 | 1.0 | 4.0 | 0.020 |

Which of the following correctly depicts the rate-concentration graph for the reaction?



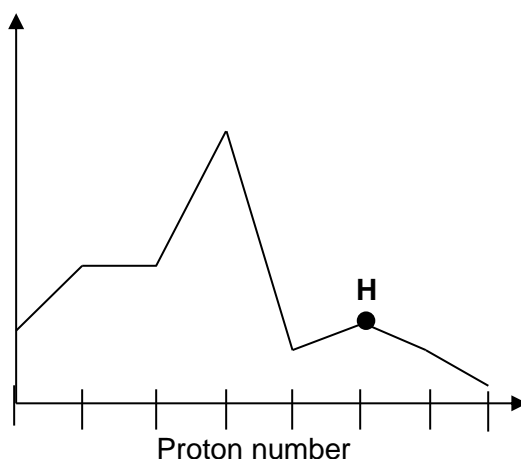
- 14 The decomposition of azomethane with time has the following rate equation. It takes 2000 s for 10 mol of azomethane to decay to 0.625 mol.

$$\text{rate} = k[\text{azomethane}]$$

What is the half-life for the decomposition of azomethane?

- A** 250 s **B** 500 s **C** 1000 s **D** 2000 s

- 15 The graph below shows a trend in the variation of a physical property of Period 3 elements.



Which of the following best describes the oxide of the element labelled **H**?

- A It is amphoteric.
 - B It is an ionic compound with covalent character.
 - C It exists as discrete molecules.
 - D It turns universal indicator blue when dissolved in water.
- 16 The ionic radii of Period 3 metals decreases across the period.

Which of the following best explains this observation?

- A More electrons are lost from the parent atom.
 - B There is less electronic shielding across the period.
 - C They are isoelectronic.
 - D The effective nuclear charge increases.
- 17 Element **J** is in Period 3 of the Periodic Table. It has a melting point of 660 °C and conducts electricity in the liquid state. The chloride of **J** is able to react with ammonia in a 1:1 ratio.

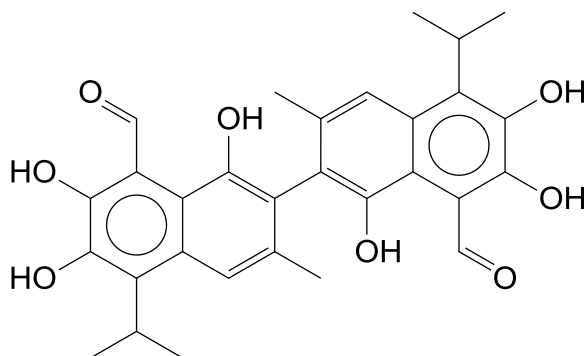
Which of the following correctly describes the structure of the chloride of **J**?

- A Metallic
- B Simple covalent
- C Giant covalent
- D Ionic

18 Which one of the following pairs of compounds does **not** have the same empirical formula?

- A $C_6H_{12}O_6$, CH_3COOH
- B C_6H_{12} , C_3H_6
- C $CHCl_3$, $Cl_3CHCHCl_3$
- D CH_3COOCH_3 , C_3H_5OH

19 Gossypol is a pigment found in cotton plants and has the following structure.



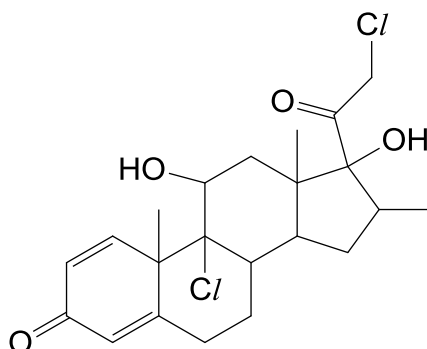
Which statement about this compound is **not** true?

- A 1 mole of Gossypol will react with 2 moles of 2,4-dinitrophenylhydrazine.
 - B 1 mole of Gossypol will react with 2 moles of Fehling's solution.
 - C Gossypol will react with sodium metal.
 - D Gossypol will react with aqueous bromine.
- 20 R-124, C_2HClF_4 , is a chlorofluorocarbon used as a refrigerant.

Which of the following statements is **not** true about R-124?

- A Hydrogen bonds are formed between its molecules.
- B It can deplete the ozone layer.
- C It does not have π bonds within the molecule.
- D The C–F bond requires a large amount of energy to break.

- 21 Mometasone is a corticosteroid that has functions similar to progesterone, an important hormone in the body.



Mometasone

Which of the following statements is **not** true about mometasone?

- A The molecular formula is $C_{22}H_{28}ClO_4$
- B After treatment with $NaOH(aq)$, it reacts with $AgNO_3(aq)$ readily.
- C It can undergo reduction when reacted with $LiAlH_4$.
- D It can be oxidised by acidified $K_2Cr_2O_7(aq)$.
- 22 A sample of 2-chlorobutane is first treated with hot $NaOH(aq)$ and then with acidified $KMnO_4(aq)$.

What is the final organic product?

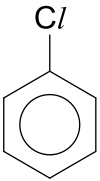
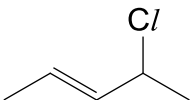
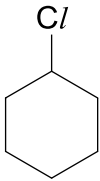
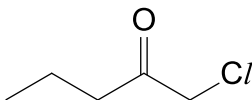
- A CH_3COOH
- B $CH_3CHCHCH_3$
- C $CH_3COCH_2CH_3$
- D $CH_3CH(COOH)CH_2CH_3$

- 23** Nitecapone is a drug that can be used to treat Parkinson's disease and has two carbonyl groups. It has the molecular formula of $C_{12}H_{11}NO_6$. When nitecapone reacts with HCN and trace amount of NaCN, a product is formed.

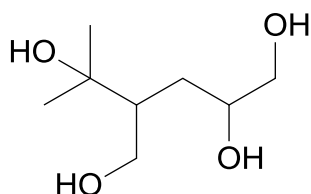
Which of the following is the molecular formula of the product?

- A** $C_{12}H_{11}N_2O_8$
B $C_{13}H_{11}N_2O_6$
C $C_{14}H_{12}N_2O_6$
D $C_{14}H_{13}N_3O_6$
- 24** Compound **X** is subjected to NaOH(aq) followed by aqueous silver nitrate at room temperature but white precipitate does not form.

What is the structure of **X**?

- A** 
- B** 
- C** 
- D** 

- 25** The compound below is heated with acidified potassium dichromate(VI) and forms an organic compound.



How many moles of sodium carbonate will react with 1 mole of the oxidised product?

- A** 0 **B** 1 **C** 1.5 **D** 2

Section B

For each of the questions in this section, one or more of the three numbered statements 1 to 3 may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses **A** to **D** should be selected on the basis of

| A | B | C | D |
|------------------------------|--------------------------------|--------------------------------|-------------------------|
| 1, 2 and 3 are correct | 1 and 2 only are correct | 2 and 3 only are correct | 1 only is correct |

No other combination of statements is used as a correct response.

- 26** Which of the following correctly define the relative molecular mass of a substance?
- 1 the mass of 1 mole of the substance compared to the mass of 1 mole of ^{12}C
 - 2 the average mass of 1 mole of the substance compared to $\frac{1}{12}$ of the mass of 1 mole of ^{12}C atoms
 - 3 the average mass of 1 molecule of the substance compared to $\frac{1}{12}$ of the mass of 1 atom of ^{12}C
- 27** Which of the following statements describe catalysts correctly?
- 1 Catalysts increase the number of molecules with energy more than activation energy.
 - 2 Catalysts affect the rate constant.
 - 3 At 40 °C, catalysts can increase the yield of a reaction.
- 28** Which of the following has a pH of 1?
- 1 0.05 mol dm⁻³ of sulfuric acid
 - 2 0.10 mol dm⁻³ of nitric acid
 - 3 0.05 mol dm⁻³ of hydrochloric acid

The responses **A** to **D** should be selected on the basis of

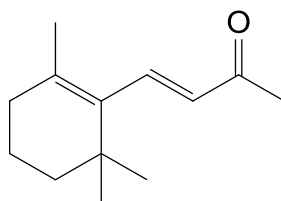
| A | B | C | D |
|------------------------------|--------------------------------|--------------------------------|-------------------------|
| 1, 2 and 3 are correct | 1 and 2 only are correct | 2 and 3 only are correct | 1 only is correct |

No other combination of statements is used as a correct response.

- 29** Element **G** is a Period 3 element and is a solid at room temperature and pressure. The oxide of **G** is soluble in water and forms a solution that turns blue litmus paper red.

Which of the following describes the chloride of **G** correctly?

- 1 It is a gas at room temperature.
 - 2 It has a formula of \mathbf{GCl}_5 .
 - 3 It hydrolyses in water to form an acidic solution.
- 30** β -ionone is a compound that is known to have the aroma of roses.



β -ionone

Which reagents will react with β -ionone?

- 1 alkaline aqueous iodide
- 2 2,4-dinitrophenylhydrazine
- 3 potassium dichromate(VI)

END OF PAPER 1

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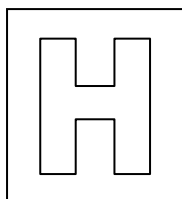
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2017 Millennia Institute 8872 H1 Prelim Paper 1 MCQ Answers

| | | | |
|-----------|---|-----------|---|
| 1 | B | 16 | D |
| 2 | D | 17 | B |
| 3 | A | 18 | D |
| 4 | A | 19 | B |
| 5 | C | 20 | A |
| 6 | D | 21 | A |
| 7 | A | 22 | C |
| 8 | D | 23 | D |
| 9 | C | 24 | A |
| 10 | B | 25 | B |
| 11 | A | 26 | C |
| 12 | C | 27 | B |
| 13 | A | 28 | B |
| 14 | B | 29 | C |
| 15 | C | 30 | B |

Candidate Name: _____

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2017 Promotional Examination II Pre-university 2

H1 CHEMISTRY

8872/02

Paper 2

11th Sep 2017

2 hours

Candidates answer Section A on the Question paper.

Additional materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

You are reminded of the need for good English and clear presentation in your answers.

Section A

Answer **all** the questions.

Section B

Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

| Question | Section A | | | | Section B | | | Total |
|----------|-----------|----|---|----|-----------|----|----|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Marks | 13 | 12 | 5 | 10 | 20 | 20 | 20 | 80 |

Section A

Answer **all** the questions in this section in the spaces provided.

- 1 (a) A sample of lead contains four stable isotopes with the following percentage abundances.

| Isotope | Percentage abundance / % |
|-------------------|--------------------------|
| ^{204}Pb | 1.4 |
| ^{206}Pb | 24.1 |
| ^{207}Pb | 22.1 |
| ^{208}Pb | a |

- (i) Define the term *relative atomic mass*.

.....
 [1]

- (ii) Determine the value of **a**. Hence, calculate the relative atomic mass of lead. Give your answer to two decimal places.

[2]

- (iii) *Use of the Data Booklet is relevant to this question.*

Determine the number of protons, neutrons and electrons in one particle of $^{206}\text{Pb}^{2+}$.

Number of protons: Number of neutrons: Number of electrons:

[1]

(b) Another element in the same group as lead is germanium, Ge, which is chemically similar to silicon, Si. The common oxidation states of germanium in compounds is +2 and +4.

(i) Draw and label the orbital in which electrons are removed from Ge to form Ge^{2+} .

[1]

(ii) Draw and label the orbital in which electrons are removed from Ge^{2+} to form Ge^{4+} .

[1]

(iii) Explain why electrons are removed from the orbital you stated in **(b)(i)** before removing electrons from the orbital in **(b)(ii)** in the ionisation of germanium.

.....
.....
.....
..... [1]

(iv) Describe the structure and bonding in germanium.

.....
.....
.....
..... [2]

(v) Compare and explain briefly how the melting point of germanium differs from that of silicon.

.....
.....
..... [2]

(c) Pure lithium is highly reactive and reacts readily with water to form lithium hydroxide and hydrogen gas.

Write the ion-electron equations for the redox processes that are occurring in this reaction.

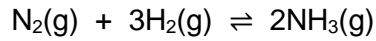
Oxidation:

Reduction:

[2]

[Total: 13]

- 2 (a) In 1905, Fritz Haber succeeded in the atmospheric 'fixing' of nitrogen with hydrogen to produce ammonia, which is a precursor in the production of fertilisers. This process is now known as the Haber process, which can be described by the chemical equation below. Haber later went on to receive a Nobel prize in 1918 for this achievement.



- (i) Describe the conditions and catalyst used in the Haber process.

.....
 [1]

- (ii) Explain how the addition of the catalyst in (a)(i) affects the position of the equilibrium for the equation above.

.....

 [2]

- (b) In aqueous solution, ammonia is a *weak Brønsted base*.

Define what is meant by the term *weak Brønsted base*.

.....
 [1]

- (c) When excess bromoethane is reacted with limited ammonia, a multi-substituted product is produced.

Write an overall equation to for the reaction when ammonia is reacted with bromoethane in the molar ratio of 1 : 2. [1]

(d) 1,1,2-trichloroethane can undergo elimination to form an alkene which exhibits geometrical isomerism.

(i) Explain how geometrical isomerism arises in alkenes.

.....
.....
.....
..... [2]

(ii) State the reagent and condition required for the elimination reaction.

..... [1]

(iii) Draw and name the structures of the two geometrical isomers.

[3]

(iv) State the number of σ and π bonds in each of the alkenes produced after elimination.

..... [1]

[Total: 12]

3 Use the third period of the modern Periodic Table, sodium to argon, to answer the following questions.

(a) Describe and explain how the atomic radii and first ionisation energies of these elements vary across the period.

.....
.....
.....
.....
.....
..... [3]

(b) State the structure and bonding present in sodium, magnesium and aluminium. Explain how the bonding present affects the variation in electrical conductivity of these elements.

.....
.....
..... [2]

[Total: 5]

- 4 Rainwater has a pH of 5.6 instead of 7.0 at 25 °C. This is because carbon dioxide in the atmosphere dissolves in the rainwater and reacts to form an equilibrium with carbonic acid, H_2CO_3 , with a K_c of $1.3 \times 10^{-3} \text{ mol}^{-1} \text{ dm}^3$. The carbonic acid then dissociates, acting as a weak Brønsted acid. Carbonic acid can be assumed to be a monoprotic acid with a K_a value of 4.27×10^{-7} .

Carbonic acid can also be found in the human blood stream as part of an acidic buffer system. When a person undergoes aerobic metabolism, the body uses oxygen to break down glucose to generate carbon dioxide and water as products. However, when a person exercises intensely, there could temporarily be insufficient oxygen for aerobic metabolism, hence producing a by-product called lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. When lactic acid is built up in the muscles faster than it could be removed by the body, the person can suffer from a condition called lactic acidosis, in which the muscles feel a burning sensation. The lactic acid produced can be removed from the system by reacting with the acidic buffer system present in blood.

- (a) Write an expression for the equilibrium constant, K_c , for the dissolution of carbon dioxide in rainwater.

[1]

- (b) (i) Construct a balanced equation, including state symbols, for the dissociation of carbonic acid in rainwater. Hence, write an expression for the acid dissociation constant of carbonic acid, K_a , and state its units.

[3]

- (ii) Calculate the concentration of H^+ ions in rainwater.

[1]

- (iii) Using your answers in (b)(i) and (b)(ii), calculate the equilibrium concentration of carbonic acid, H_2CO_3 , in water. You may assume that the equilibrium concentration of H^+ ions in rainwater is the same as the concentration of HCO_3^- ions.

[1]

- (c) Write a balanced equation to show how small amounts of lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ can be removed by the buffer system present in blood.

..... [1]

- (d) Lactic acid can be synthesised in the laboratory from ethanal, CH_3CHO , in two steps.

State the reagents and conditions for both steps and draw the structure of the intermediate organic compound in the space below.

Structure of intermediate:

Reagents and conditions for

Step 1:

Step 2: [3]

[Total: 10]

Section B

Answer **two** questions from this section on separate answer paper.

- 5 (a) The boiling points of the halogens show the following trend.

| Element | boiling point / °C |
|---------|--------------------|
| Cl_2 | -35 |
| Br_2 | 59 |
| I_2 | 184 |

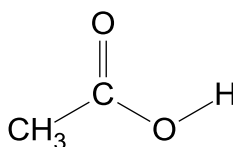
Explain, in terms of structure and bonding, the trend in the boiling point. [2]

- (b) The table shows the melting points of magnesium chloride and magnesium oxide respectively.

| compound | melting point / °C |
|----------|--------------------|
| $MgCl_2$ | 714 |
| MgO | 2852 |

Account for the difference in the melting point of the two compounds in terms of their structure and bonding. [3]

- (c) The structural formula of ethanoic acid is given below.



Explain, with the aid of a diagram, why ethanoic acid has a M_r of 120 in organic solvent. [2]

- (d) (i) Define, with the aid of an equation, the standard enthalpy change of combustion of propane, C_3H_8 . [2]
- (ii) Calculate the enthalpy change of formation of propane, given the following data.

| | |
|---|-----------------------------|
| Standard enthalpy change of combustion of propane | $-2220 \text{ kJ mol}^{-1}$ |
| Standard enthalpy change of formation of water | -285 kJ mol^{-1} |
| Standard enthalpy change of formation of carbon dioxide | -394 kJ mol^{-1} |

[1]

- (iii) Propane is combusted under an open copper container with 2 dm³ of water at 29.0 °C.

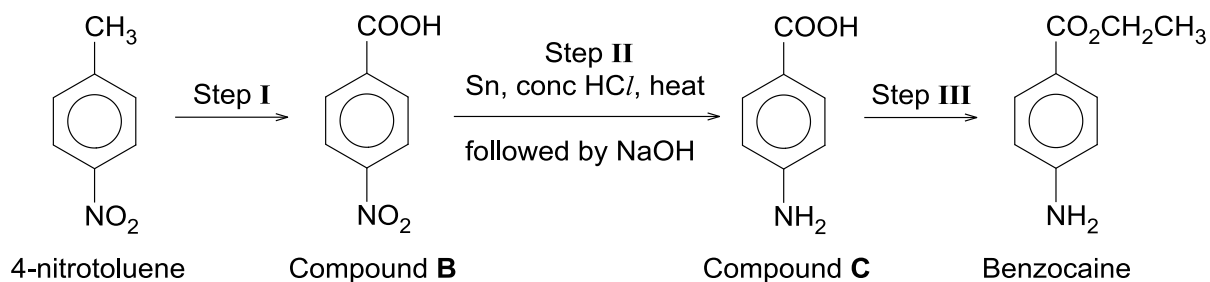
Using the data given below and in (d)(ii), calculate the change in temperature of the water if 11.0 g of propane is combusted. Assume that the efficiency of heat transfer is 75%.

Specific heat capacity of water = 4.20 J g⁻¹ K⁻¹

Density of water = 1.0 g cm⁻³ [3]

- (iv) Suggest a reason to explain why the efficiency of heat transfer is not 100%. [1]

- (e) Benzocaine is a topical anaesthetic used in first aid creams and sunburn remedies. It can be produced from 4-nitrotoluene in a series of steps.



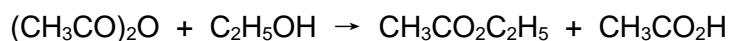
- (i) State the reagents and conditions used for steps I and III. [2]
- (ii) State the type of reaction for steps I and III. [2]
- (iii) Explain why the NaOH in step II needs to be added carefully in order to obtain compound C. [1]
- (iv) Write a balanced equation for step III. [1]

[Total: 20]

- 6 (a) 2.78 g of a metallic oxide, represented by M_2O (where M is an unknown metal), was added to 43.7 cm^3 of 1.50 mol dm^{-3} hydrochloric acid. The resulting solution then required 13.0 cm^3 of $0.500 \text{ mol dm}^{-3}$ aqueous sodium hydroxide for neutralisation.

Construct two balanced equations for the reactions that occur. Hence, determine the relative atomic mass of M . [4]

- (b) The reaction of ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$, with ethanol, $\text{C}_2\text{H}_5\text{OH}$, can be represented by the equation:



The table below shows the initial concentrations of the two reactants and the initial rates of reaction.

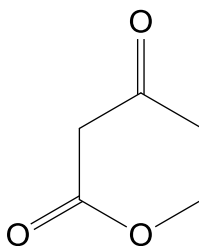
| Experiment | $[(\text{CH}_3\text{CO})_2\text{O}]$ / mol dm^{-3} | $[\text{C}_2\text{H}_5\text{OH}]$ / mol dm^{-3} | Initial rate / $\text{mol dm}^{-3} \text{ s}^{-1}$ |
|------------|--|---|---|
| 1 | 0.800 | 0.400 | 1.20×10^{-3} |
| 2 | 0.800 | 0.800 | 2.40×10^{-3} |
| 3 | 1.60 | 0.800 | 4.80×10^{-3} |

- (i) Deduce the order of the reaction with respect to each of ethanoic anhydride and ethanol. [2]
- (ii) Write an expression for the rate equation. [1]
- (iii) Calculate the value, with units, for the rate constant, k . [1]
- (iv) With the aid of a diagram, explain how a catalyst increases the rate of a chemical reaction. [3]

- (c) On heating a neutral compound **D** (shown below) with dilute sulfuric acid, a single compound **E** ($C_5H_8O_4$) is produced. Both compounds **D** and **E** give an orange precipitate with 2,4-dinitrophenylhydrazine but do not react with Fehling's solution.

Upon treating **E** with HCN with a trace of NaCN, **F** ($C_6H_9O_4N$) is produced.

F gives **G** ($C_6H_{15}O_3N$) on reacting with lithium aluminum hydride in dry ether. **G** forms **H** ($Na_2C_6H_9O_5N$) when reacted with hot $KMnO_4$ in dilute NaOH.



Compound **D**

Suggest the structures of **E** to **H**, explaining the chemistry of the reactions described.

Write a balanced equation for the reaction of **D** with 2,4-dinitrophenylhydrazine.

[9]

[Total: 20]

- 7 (a) Bromine trifluoride auto-ionises in the liquid state according to the equation.



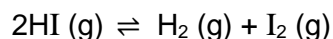
Draw the 'dot-and-cross' diagrams to show the outer shell electron arrangement of BrF_3 and BrF_4^- . Hence, predict the shapes of the two structures. [2]

- (b) Boron forms simple trihalides of formula BX_3 with all the halogens. BF_3 and BCl_3 are commonly used as catalyst in chemical reactions since they readily react with electron pair donors.

(i) Using VSEPR theory, explain the shape and state the bond angle of BF_3 . [3]

(ii) BF_3 and trimethylamine, $(\text{CH}_3)_3\text{N}$ react in a 1:1 ratio to give a white crystalline compound. Draw a diagram to illustrate and explain the type of bonding involved in the formation of the compound. [3]

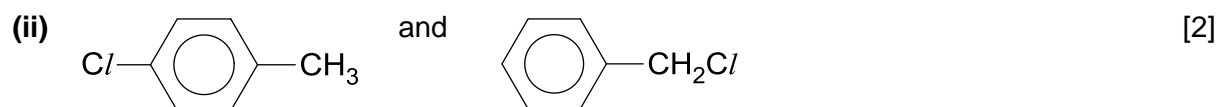
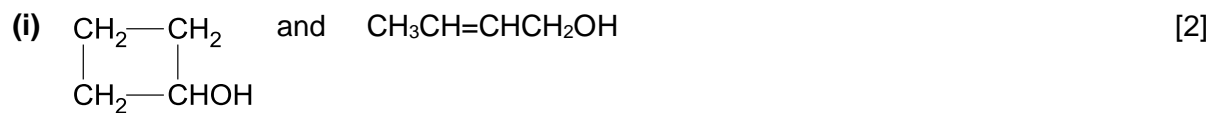
- (c) Pure hydrogen iodide, HI , is a gas, which at high temperatures, partially decomposes into hydrogen and iodine, according to the equation:



At 500 K, the equilibrium constant, K_c , for the decomposition reaction is 6.25×10^{-3} . Some pure HI is placed into an evacuated 2.0 dm^3 glass tube and heated to 500 K. In the equilibrium sample, the concentration of I_2 is $3.10 \times 10^{-5} \text{ mol dm}^{-3}$.

- (i) Calculate the concentrations of $\text{H}_2(\text{g})$ and $\text{HI}(\text{g})$ in this equilibrium mixture at 500 K. [2]
- (ii) Calculate the amount of HI that must have been placed in the 2.0 dm^3 glass tube originally. [2]
- (iii) At 600 K, the K_c for dissociation of HI is 1.56×10^{-2} . Deduce whether the forward reaction is endothermic or exothermic. [2]

- (d) Suggest simple one-step test-tube reactions by which the following pairs of isomers can be distinguished from each other. You should state the reagents and conditions for each test, and describe the observations for each of the isomers in the pair.



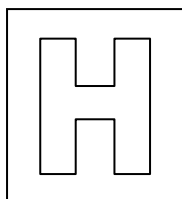
[Total: 20]

END OF PAPER 2

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2017 Promotional Examination II Pre-university 2

H1 CHEMISTRY

8872/02

Paper 2

11th Sep 2017

2 hours

Candidates answer Section A on the Question paper.

Additional materials: Answer Paper
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not turn over this question paper until you are told to do so

Write your name, class and admission number on all the work you hand in.

Write in dark blue or black pen.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

You are reminded of the need for good English and clear presentation in your answers.

Section A

Answer **all** the questions.

Section B

Answer **two** questions on separate answer paper.

At the end of the examination, fasten all your work securely together.

The number of marks is given in brackets [] at the end of each question or part question.

| Question | Section A | | | | Section B | | | Total |
|----------|-----------|----|---|----|-----------|----|----|-------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | |
| Marks | 13 | 12 | 5 | 10 | 20 | 20 | 20 | 80 |

Section A

Answer **all** the questions in this section in the spaces provided.

- 1 (a) A sample of lead contains four stable isotopes with the following percentage abundances.

| Isotope | Percentage abundance / % |
|-------------------|--------------------------|
| ^{204}Pb | 1.4 |
| ^{206}Pb | 24.1 |
| ^{207}Pb | 22.1 |
| ^{208}Pb | a |

- (i) Define the term *relative atomic mass*.

.....
 [1]

Relative atomic mass is the weighted average isotopic mass of one atom of an element compared to $^{12}_6\text{C}$ the mass of a ^{12}C atom. ;

- (ii) Determine the value of **a**. Hence, calculate the relative atomic mass of lead. Give your answer to two decimal places.

[2]

$$\% \text{ abundance of } ^{208}\text{Pb}, a = 100 - 1.4 - 24.1 - 22.1 = 52.4\% ;$$

$$\begin{aligned} \text{Relative atomic mass of lead} \\ &= (204 \times 1.4\%) + (206 \times 24.1\%) + (207 \times 22.1\%) + (208 \times 52.4\%) \\ &= 207.24 \text{ (2 d.p.)} ; \end{aligned}$$

- (iii) *Use of the Data Booklet is relevant to this question.*

Determine the number of protons, neutrons and electrons in one particle of $^{206}\text{Pb}^{2+}$.

Number of protons: Number of neutrons: Number of electrons:

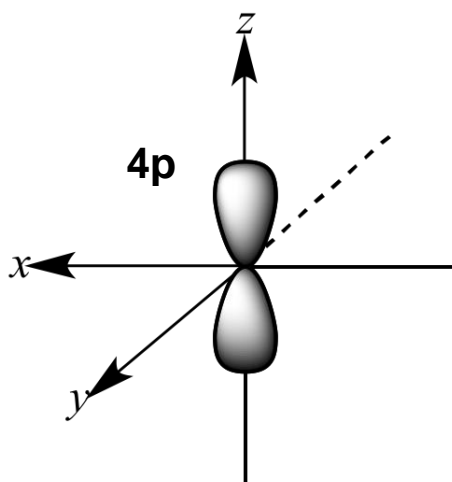
[1]

Number of protons: 82 Number of neutrons: 124 Number of electrons: 80 ;

(b) Another element in the same group as lead is germanium, Ge, which is chemically similar to silicon, Si. The common oxidation states of germanium in compounds is +2 and +4.

(i) Draw and label the orbital in which electrons are removed from Ge to form Ge^{2+} .

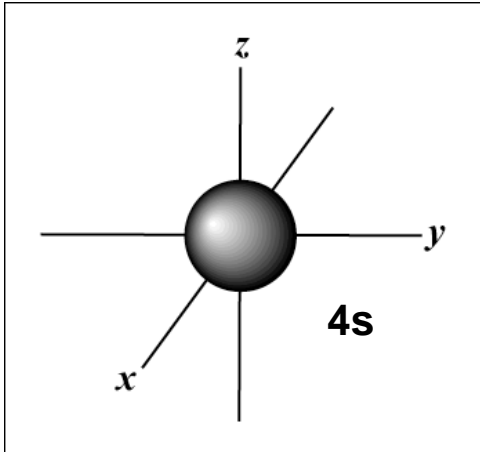
[1]



(axis not required)

(ii) Draw and label the orbital in which electrons are removed from Ge^{2+} to form Ge^{4+} .

[1]



- (iii) Explain why electrons are removed from the orbital you stated in (b)(i) before removing electrons from the orbital in (b)(ii) in the ionisation of germanium.

.....

 [1]

The electrons in the 4p orbital are further from nucleus and experiences additional shielding from the 4s electrons. Less energy is required and it is easier to remove from a valence electron from the 4p than 4s orbital ;

- (iv) Describe the structure and bonding in germanium.

.....

 [2]

Germanium has a giant covalent structure with strong covalent bonds between atoms / strong electrostatic forces of attraction between positive Ge nuclei and the shared pair of electrons.

- (v) Compare and explain briefly how the melting point of germanium differs from that of silicon.

.....

 [2]

The melting point of germanium will be lower than silicon. ;

Atomic radius of Ge is larger than Si OR Ge has longer bond length than Si and less effective overlap of orbitals resulting in weaker covalent bonds. ;

- (c) Pure lithium is highly reactive and reacts readily with water to form lithium hydroxide and hydrogen gas.

Write the ion-electron equations for the redox processes that are occurring in this reaction.

Oxidation:

Reduction:

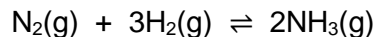
[2]

[Total: 13]

Oxidation: $\text{Li} \rightarrow \text{Li}^+ + \text{e}^-$

Reduction: $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$

- 2 (a) In 1905, Fritz Haber succeeded in the atmospheric 'fixing' of nitrogen with hydrogen to produce ammonia, which is a precursor in the production of fertilisers. This process is now known as the Haber process, which can be described by the chemical equation below. Haber later went on to receive a Nobel prize in 1918 for this achievement.



- (i) Describe the conditions and catalyst used in the Haber process.

.....
 [1]

450 °C, 200-300 atm, finely divided Fe catalyst (and Al₂O₃ promoter) ;

- (ii) Explain how the addition of the catalyst in (a)(i) affects the position of the equilibrium for the equation above.

.....

 [2]

[Turn over

The equilibrium position does not change as the catalyst increases the rate of the forward and backward reactions to the same extent. ;

- (b) In aqueous solution, ammonia is a *weak Brønsted base*.

Define what is meant by the term *weak Brønsted base*.

.....
 [1]

A weak Brønsted base dissociates partially in water to accept H⁺ ions / protons

- (c) When excess bromoethane is reacted with limited ammonia, a multi-substituted product is produced.

Write an overall equation for the reaction when ammonia is reacted with bromoethane in the molar ratio of 1 : 2. [1]



- (d) 1,1,2-trichloroethane can undergo elimination to form an alkene which exhibits geometrical isomerism.

- (i) Explain how geometrical isomerism arises in alkenes.

.....

 [2]

There is restricted rotation about the π bond ;

and the two groups attached to each adjacent carbon are different. ;

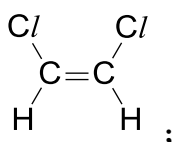
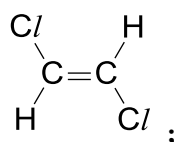
- (ii) State the reagent and condition required for the elimination reaction.

..... [1]

ethanolic KOH, heat under reflux ;

- (iii) Draw and name the structures of the two geometrical isomers.

[3]

**cis-1,2-dichloroethene****trans-1,2-dichloroethene ; (both names)**

(iv) State the number of σ and π bonds in each of the alkenes produced after elimination.

..... [1]

[Total: 12]

5 σ bonds and 1 π bond. ;

3 Use the third period of the modern Periodic Table, sodium to argon, to answer the following questions.

(a) Describe and explain how the atomic radii and first ionisation energies of these elements vary across the period.

.....

.....

.....

.....

.....

.....

..... [3]

[Turn over

Atomic radius generally decrease while first ionisation energies generally increase across the period. ;

Across the period, nuclear charge increases (as proton no. increases) while the increase in shielding effect is negligible. Effective nuclear charge increases ;

Hence, attraction for the valence electrons increases, distance of valence electrons from nucleus decreases. More energy is required remove a valence electron from the outer shell. ;

- (b) State the structure and bonding present in sodium, magnesium and aluminium. Explain how the bonding present affects the variation in electrical conductivity of these elements.

.....

 [2]

[Total: 5]

Sodium, magnesium and aluminium have giant metallic lattice structure with strong electrostatic forces of attraction between positively charged cations and negatively charged delocalised electrons. ;

As the number of delocalised electrons increases from sodium to aluminium, there are more mobile charge carriers. Hence electrical conductivity increases from sodium to aluminium. ;

- 4 Rainwater has a pH of 5.6 instead of 7.0 at 25 °C. This is because carbon dioxide in the atmosphere dissolves in the rainwater and reacts to form an equilibrium with carbonic acid, H_2CO_3 , with a K_c of $1.3 \times 10^{-3} \text{ mol}^{-1} \text{ dm}^3$. The carbonic acid then dissociates, acting as a weak Brønsted acid. Carbonic acid can be assumed to be a monoprotic acid with a K_a value of 4.27×10^{-7} .

Carbonic acid can also be found in the human blood stream as part of an acidic buffer system. When a person undergoes aerobic metabolism, the body uses oxygen to break down glucose to generate carbon dioxide and water as products. However, when a person exercises intensely, there could temporarily be insufficient oxygen for aerobic metabolism, hence producing a by-product called lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$. When lactic acid is built up in the muscles faster than it could be removed by the body, the person can suffer from a condition called lactic acidosis, in which the muscles feel a burning sensation. The lactic acid produced can be removed from the system by reacting with the acidic buffer system present in blood.

- (a) Write an expression for the equilibrium constant, K_c , for the dissolution of carbon dioxide in rainwater.

[1]

$$K_c = \frac{[\text{H}_2\text{CO}_3]}{[\text{H}_2\text{O}][\text{CO}_2]} ;$$

- (b) (i) Construct a balanced equation, including state symbols, for the dissociation of carbonic acid in rainwater. Hence, write an expression for the acid dissociation constant of carbonic acid, K_a , and state its units.

[3]



$$K_a = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} ;$$

Units: mol dm^{-3} ;

- (ii) Calculate the concentration of H^+ ions in rainwater.

[1]

$$[\text{H}^+] = 10^{-5.6} = 2.512 \times 10^{-6} = 2.51 \times 10^{-6} \text{ mol dm}^{-3} \text{ (3 s.f.)}$$

- (iii) Using your answers in (b)(i) and (b)(ii), calculate the equilibrium concentration of carbonic acid, H_2CO_3 , in water. You may assume that the equilibrium concentration of H^+ ions in rainwater is the same as the concentration of HCO_3^- ions.

[1]

$$K_a = \frac{[\text{H}^+][\text{HCO}_3^-]}{[\text{H}_2\text{CO}_3]} = \frac{[\text{H}^+]^2}{[\text{H}_2\text{CO}_3]}$$

$$[\text{H}_2\text{CO}_3] = (2.512 \times 10^{-6})^2 \div (4.266 \times 10^{-7})$$

$$= 1.479 \times 10^{-5} = \underline{1.48 \times 10^{-5} \text{ mol dm}^{-3} \text{ (3 s.f.)}} \quad ;$$

(do not penalise units here. Marks awarded for units in (b)(i))

- (c) Write a balanced equation to show how small amounts of lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$ can be removed by the buffer system present in blood.

..... [1]



- (d) Lactic acid can be synthesised in the laboratory from ethanal, CH_3CHO , in two steps.

State the reagents and conditions for both steps and draw the structure of the intermediate organic compound in the space below.

Structure of intermediate:

Reagents and conditions for

Step 1:

Step 2: [3]

[Total: 10]

Intermediate: $\text{CH}_3\text{CH}(\text{OH})\text{CN}$

Step 1: HCN , trace NaOH / NaCN / KCN , $10\text{-}20^\circ\text{C}$;

Step 2: dilute H_2SO_4 , heat under reflux ;

Section B

Answer **two** questions from this section on separate answer paper.

- 5 (a) The boiling points of the halogens show the following trend.

| Element | boiling point / °C |
|-----------------|--------------------|
| Cl ₂ | -35 |
| Br ₂ | 59 |
| I ₂ | 184 |

Explain, in terms of structure and bonding, the trend in the boiling point. [2]

Halogens have simple molecular structures, consisting of non-polar molecules held together by weak van der Waals' forces between molecules.

Down the group, the molecules becomes larger and the no. of electrons to be polarized increases / electron cloud size to be polarised increases. Thus, van der Waals' forces of attraction become stronger. More energy required to overcome the intermolecular forces of attraction. Hence, boiling points increase.

- (b) The table shows the melting points of magnesium chloride and magnesium oxide respectively.

| compound | melting point / °C |
|-------------------|--------------------|
| MgCl ₂ | 714 |
| MgO | 2852 |

Account for the difference in the melting point of the two compounds in terms of their structure and bonding. [3]

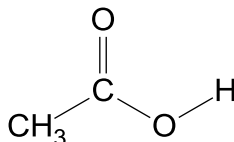
MgO and MgCl₂ are have giant ionic lattice structure with strong electrostatic forces of attraction between oppositely charged ions. [1]

$$|\text{lattice energy}| \propto \left| \frac{q_+ \times q_-}{r_+ + r_-} \right|$$

Both compounds have the same cation, but charge of O²⁻ is greater than that Cl⁻ and ionic radius of O²⁻ is smaller than that of Cl⁻. [1]

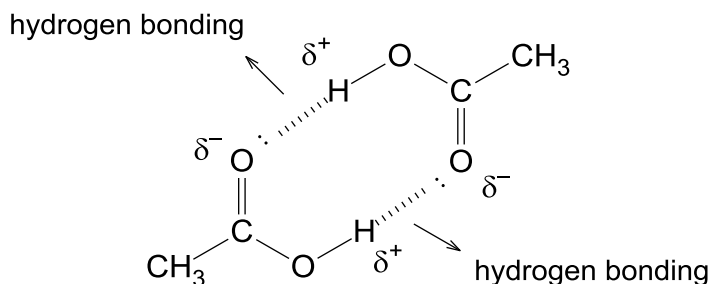
Thus, the magnitude of lattice energy of MgO is greater than that of MgCl_2 , indicating that the ionic bonds of MgO is stronger. Hence more energy is required to break the stronger ionic bonds in MgO compared to MgCl_2 . [1]

- (c) The structural formula of ethanoic acid is given below.



Explain, with the aid of a diagram, why ethanoic acid has a M_r of 120 in organic solvent. [2]

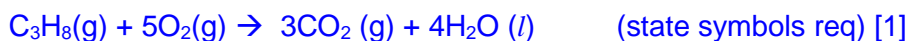
The apparent M_r is 120 which is twice that of M_r of ethanoic acid. Ethanoic acid dimerises in organic solvent through the formation of intermolecular hydrogen bonding.



(Must have partial positive and negative signs, lone pair of electron on the oxygen and label the hydrogen bonds.)

- (d) (i) Define, with the aid of an equation, the standard enthalpy change of combustion of propane, C_3H_8 . [2]

Standard enthalpy change of combustion, ΔH_c^\ominus , of propane is the enthalpy change when 1 mole of the propane is completely burnt in excess oxygen under standard conditions of 298K and 1 atm. [1]



- (ii) Calculate the enthalpy change of formation of propane, given the following data.

| | |
|---|-----------------------------|
| Standard enthalpy change of combustion of propane | $-2220 \text{ kJ mol}^{-1}$ |
| Standard enthalpy change of formation of water | -285 kJ mol^{-1} |
| Standard enthalpy change of formation of carbon dioxide | -394 kJ mol^{-1} |

Let x be the enthalpy change of formation of propane.

$\Delta H_c^\theta = \text{sum of } \Delta H_f^\theta \text{ (products)} - \text{sum of } \Delta H_f^\theta \text{ (reactants)}$ OR energy cycle

$$-2220 = [3(-394) + 4(-285)] - (x)$$

$$x = -102 \text{ kJ mol}^{-1} \quad [1]$$

- (iii) Propane is combusted under an open copper container with 2 dm^3 of water at 29.0°C .

Using the data given below and in (d)(ii), calculate the change in temperature of the water if 11.0 g of propane is combusted. Assume that the efficiency of heat transfer is 75% .

Specific heat capacity of water = $4.20 \text{ J g}^{-1} \text{ K}^{-1}$

Density of water = 1.0 g cm^{-3}

[3]

Mr of propane, $\text{C}_3\text{H}_8 = 3 \times 12.0 + 8 \times 1.0 = 44.0$

Amt of propane = $11.0 \div 44.0 = 0.25 \text{ mol}$;

Heat transferred to 2 dm^3 water

= Heat released by combustion of propane $\times 75\%$

= $(2220 \times 10^3)(0.25) \times 75\% = 416.25 \text{ kJ} = 416\,250 \text{ J}$;

$Q = mc\Delta T$

$416\,250 = (2000)(4.20) \Delta T$

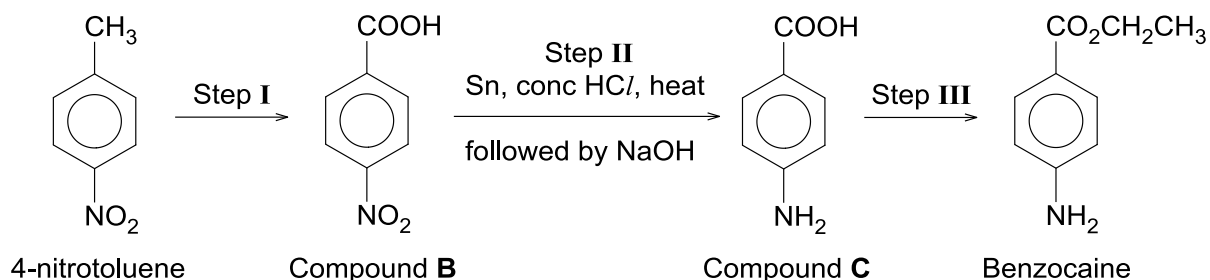
$\Delta T = \underline{49.6^\circ\text{C (3 s.f.)}$;

- (iv) Suggest a reason to explain why the efficiency of heat transfer is not 100% .

[1]

Heat is lost to the surroundings [1]

- (e) Benzocaine is a topical anaesthetic used in first aid creams and sunburn remedies. It can be produced from 4-nitrotoluene in a series of steps.



- (i) State the reagents and conditions used for steps I and III. [2]

Step I: KMnO_4 , dil. H_2SO_4 , heat with reflux [1]

Step III: $\text{CH}_3\text{CH}_2\text{OH}$, conc H_2SO_4 , heat with reflux [1]

- (ii) State the type of reaction for steps I and III. [2]

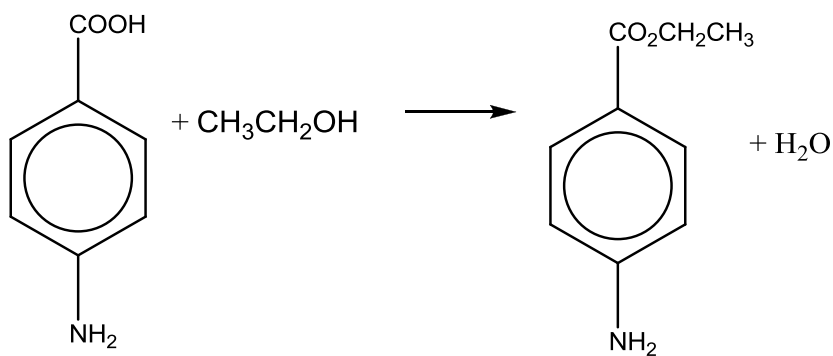
Step I: Oxidation [1]

Step III: Substitution/Condensation/Esterification [1]

- (iii) Explain why the NaOH in step II needs to be added carefully in order to obtain compound C. [1]

If too much NaOH is added, the carboxylic acid may exist as a carboxylate salt. [1]

- (iv) Write a balanced equation for step III. [1]



[Total: 20]

- 6 (a) 2.78 g of a metallic oxide, represented by M_2O (where M is an unknown metal), was added to 43.7 cm^3 of 1.50 mol dm^{-3} hydrochloric acid. The resulting solution then required 13.0 cm^3 of $0.500 \text{ mol dm}^{-3}$ aqueous sodium hydroxide for neutralisation.

Construct two balanced equations for the reactions that occur. Hence, determine the relative atomic mass of M . [4]



$$\text{No of moles of NaOH} = 13.0/1000 \times 0.5 = 6.5 \times 10^{-3} \text{ mol}$$

$$\text{No of moles of HCl in the resulting solution} = 6.5 \times 10^{-3} \text{ mol}$$

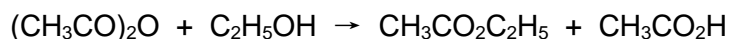
$$\begin{aligned} \text{No of moles of HCl that has reacted with } M_2O &= (43.7/1000 \times 1.50) - (6.5 \times 10^{-3}) \\ &= 0.05905 \text{ mol} \quad [1] \end{aligned}$$

$$\text{No of moles of } M_2O = 0.05905/2 = 0.029525 \text{ mol} \quad [1]$$

$$\text{Mr of } M_2O = 2.78/0.029525 = 94.2$$

$$\text{Ar of } M = (94.2 - 16)/2 = 39.1 \quad [1]$$

- (b) The reaction of ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$, with ethanol, $\text{C}_2\text{H}_5\text{OH}$, can be represented by the equation:



The table below shows the initial concentrations of the two reactants and the initial rates of reaction.

| Experiment | $[(\text{CH}_3\text{CO})_2\text{O}]$ /mol dm ⁻³ | $[\text{C}_2\text{H}_5\text{OH}]$ /mol dm ⁻³ | Initial rate /mol dm ⁻³ s ⁻¹ |
|------------|---|--|---|
| 1 | 0.800 | 0.400 | 1.20×10^{-3} |
| 2 | 0.800 | 0.800 | 2.40×10^{-3} |
| 3 | 1.60 | 0.800 | 4.80×10^{-3} |

- (i) Deduce the order of the reaction with respect to each of ethanoic anhydride and ethanol. [2]

$$\text{Rate} = k [(\text{CH}_3\text{CO})_2\text{O}]^x [\text{C}_2\text{H}_5\text{OH}]^y$$

$$\text{Rate} = k [(\text{CH}_3\text{CO})_2\text{O}]^x [\text{C}_2\text{H}_5\text{OH}]^y$$

Comparing experiment 1 and 2

Comparing experiment 2 and 3

When $[C_2H_5OH]$ doubles, initial rate doubles, therefore

$$y = 1$$

order with respect to $C_2H_5OH = 1$;

When $[(CH_3CO)_2O]$ doubles, initial rate doubles, therefore

$$x = 1$$

order with respect to $CH_3CO)_2O = 1$;

- (ii) Write an expression for the rate equation. [1]

$$\text{Rate} = k [CH_3CO)_2O][C_2H_5OH] ;$$

- (iii) Calculate the value, with units, for the rate constant, k. [1]

Using values from experiment 1:

$$1.20 \times 10^{-3} = k (0.800)(0.400)$$

$$k = 3.75 \times 10^{-3} \text{ mol}^{-1} \text{ dm}^3 \text{ s}^{-1} ;$$

- (iv) With the aid of a diagram, explain how a catalyst increases the rate of a chemical reaction. [3]

✚ Catalyst increases the rate of reaction by providing an alternative pathway of lower activation energy

✚ Number of reactant particles with $E \geq E_a$ increases

✚ Frequency of effective collisions increases, rate increases

[all 3 points: 2m ; 1-2 points: 1m]

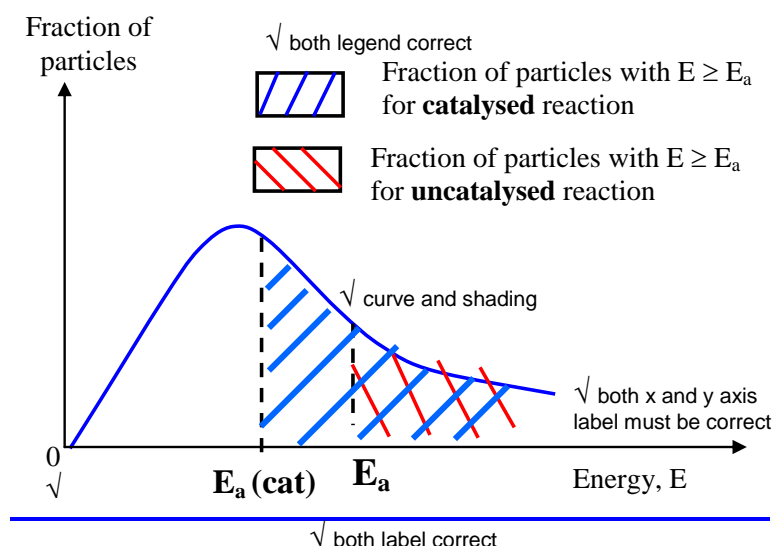


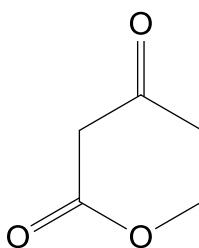
Diagram and legend [1m]

Must be correct graph to award any marks.

- (c) On heating a neutral compound **D** (shown below) with dilute sulfuric acid, a single compound **E** ($C_5H_8O_4$) is produced. Both compounds **D** and **E** give an orange precipitate with 2,4-dinitrophenylhydrazine but do not react with Fehling's solution.

Upon treating **E** with HCN with a trace of NaCN, **F** ($C_6H_9O_4N$) is produced.

F gives **G** ($C_6H_{15}O_3N$) on reacting with lithium aluminum hydride in dry ether. **G** forms **H** ($Na_2C_6H_9O_5N$) when reacted with hot $KMnO_4$ in dilute NaOH.



Compound **D**

Suggest the structures of **E** to **H**, explaining the chemistry of the reactions described.

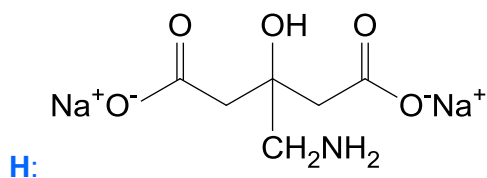
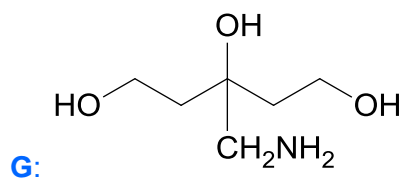
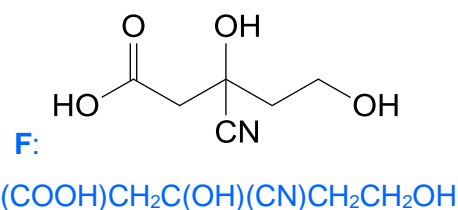
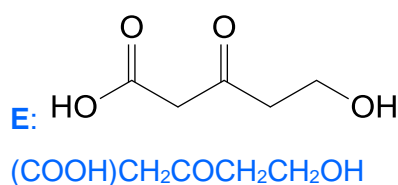
Write a balanced equation for the reaction of **D** with 2,4-dinitrophenylhydrazine.

[9]

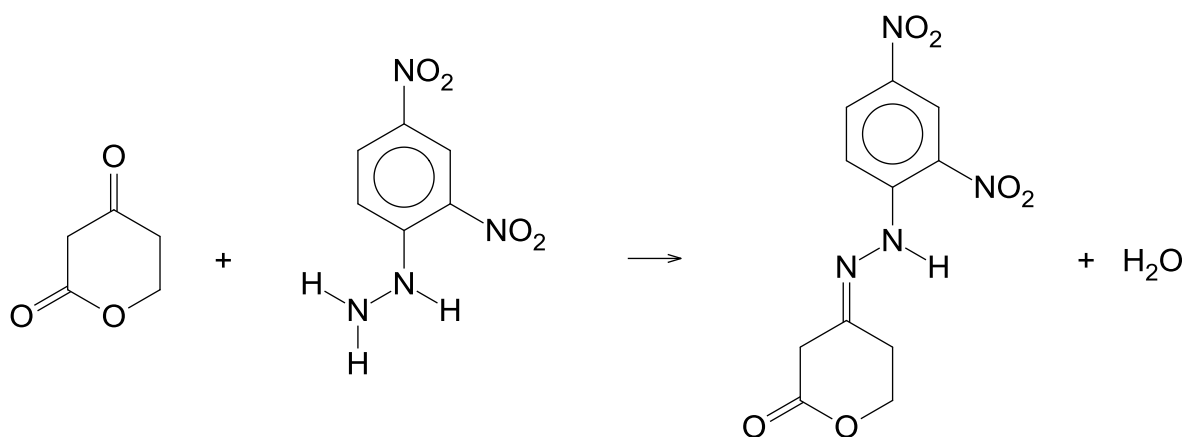
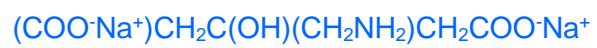
[Total: 20]

- **D** undergoes acid hydrolysis to form **E**
- **D** and **E** give orange ppt with 2,4 DNPH \rightarrow condensation, carbonyl group present
- **D** and **E** does not react with Fehling's \rightarrow absence of aliphatic aldehyde group
- **E** undergoes addition with HCN to form **F**
- **F** undergoes reduction/hydrogenation to give **G**.
- **G** undergoes oxidation with alkaline $KMnO_4$ to form **H**

(capped at maximum of 4m, 8 ticks)



[Turn over

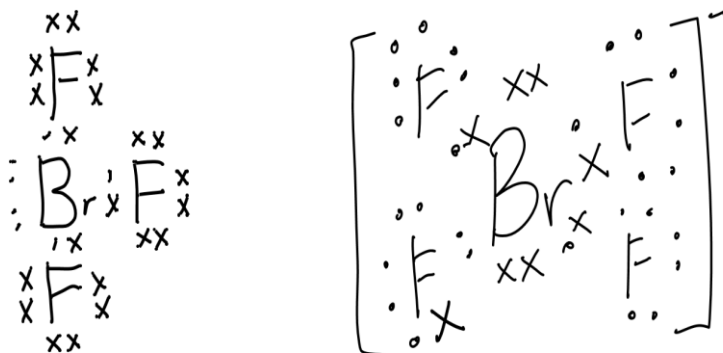


(each structure and equation 1 mark)

- 7 (a) Bromine trifluoride auto-ionises in the liquid state according to the equation.



Draw the 'dot-and-cross' diagrams to show the outer shell electron arrangement of BrF_3 and BrF_4^- . Hence, predict the shapes of the two structures. [2]



T-shaped (3bp 2lp)

(Square Planar (4bp 2lp))

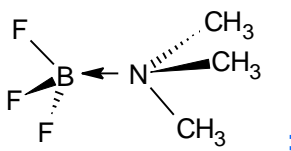
- (b) Boron forms simple trihalides of formula BX_3 with all the halogens. BF_3 and BCl_3 are commonly used as catalyst in chemical reactions since they readily react with electron pair donors.

- (i) Using VSEPR theory, explain the shape and state the bond angle of BF_3 . [3]

BF_3 molecule has trigonal planar [1m] shape because to minimise repulsion the 3 bond pairs will be arranged as far apart as possible. [1m]

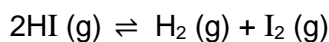
Bond angle is 120° [1m]

- (ii) BF_3 and trimethylamine, $(\text{CH}_3)_3\text{N}$ react in a 1:1 ratio to give a white crystalline compound. Draw a diagram to illustrate and explain the type of bonding involved in the formation of the compound. [3]



In BF_3 , there are only six electrons around the central atom hence, B is electron deficient. B in BF_3 has an energetically accessible vacant orbital to accept a lone pair of electrons ; from N to form a dative bond. ;

- (c) Pure hydrogen iodide, HI, is a gas, which at high temperatures, partially decomposes into hydrogen and iodine, according to the equation:



At 500 K, the equilibrium constant, K_c , for the decomposition reaction is 6.25×10^{-3} . Some pure HI is placed into an evacuated 2.0 dm^3 glass tube and heated to 500 K. In the equilibrium sample, the concentration of I_2 is $3.10 \times 10^{-5} \text{ mol dm}^{-3}$.

- (i) Calculate the concentrations of $\text{H}_2 \text{(g)}$ and HI (g) in this equilibrium mixture at 500 K. [2]

$$[\text{H}_2] = [\text{I}_2] = 3.10 \times 10^{-5} \text{ mol dm}^{-3} \text{ [1]}$$

$$K_c = \frac{[\text{H}_2][\text{I}_2]}{[\text{HI}]^2}$$

$$6.25 \times 10^{-3} = \frac{(3.10 \times 10^{-5})^2}{[\text{HI}]^2}$$

$$[\text{HI}] = 3.92 \times 10^{-4} \text{ mol dm}^{-3} \text{ [1]}$$

- (ii) Calculate the amount of HI that must have been placed in the 2.0 dm^3 glass tube originally. [2]

| | | | | | |
|--------------------------------|--------------------------|----------------------|-------------------------|---|-------------------------|
| | 2HI (g) | \rightleftharpoons | $\text{H}_2 \text{(g)}$ | + | $\text{I}_2 \text{(g)}$ |
| Initial / mol dm^{-3} | x | | 0 | | 0 |
| change / mol dm^{-3} | $-2(3.1 \times 10^{-5})$ | | $+3.1 \times 10^{-5}$ | | $+3.1 \times 10^{-5}$ |
| equil / mol dm^{-3} | 3.92×10^{-4} | | 3.1×10^{-5} | | 3.1×10^{-5} |

$$\text{Initial } [\text{HI}] = 3.92 \times 10^{-4} + 2(3.1 \times 10^{-5}) = 4.54 \times 10^{-4} \text{ mol dm}^{-3} \text{ [1]}$$

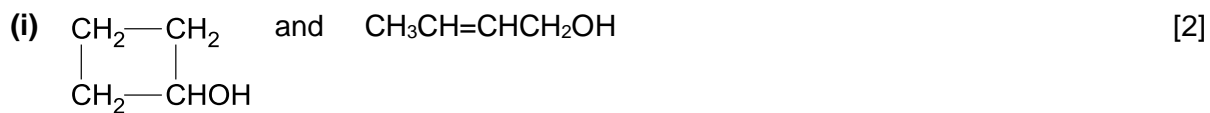
$$\text{Initial amount of HI} = 2(4.54 \times 10^{-4}) \text{ mol}$$

$$= 9.08 \times 10^{-4} \text{ mol [1]}$$

- (iii) At 600 K, the K_c for dissociation of HI is 1.56×10^{-2} . Deduce whether the forward reaction is endothermic or exothermic. [2]

As temperature increases, by Le Chatelier's Principle, the system will respond in a way to decrease the temperature. Since K_c increases, this implies that the position of equilibrium shifts to the right (products). ; favoring endothermic reaction, which is the forward reaction. ;

- (d) Suggest simple one-step test-tube reactions by which the following pairs of isomers can be distinguished from each other. You should state the reagents and conditions for each test, and describe the observations for each of the isomers in the pair.



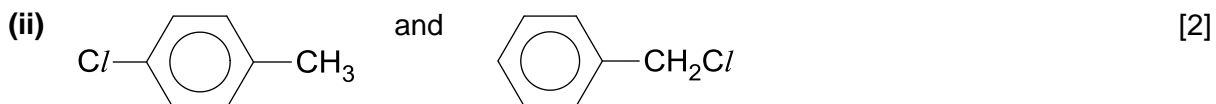
Test: Add aqueous bromine to each sample [1]

Observation:



$\text{CH}_3\text{CH}=\text{CHCH}_2\text{OH}$: orange aqueous bromine decolourises

Both observation correct: [1]



Test: NaOH and heat. Add HNO_3 , followed by AgNO_3 . [1]

Obs:



Both observation correct: [1]



[Total: 20]

Test: add aqueous I_2 in aqueous NaOH, warm. [1]

[Turn over

Obs:

$\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$: yellow ppt of CHI_3 formed

$\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$: No yellow ppt

Both observation correct: [1]

END OF PAPER 2

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