Name:_____ Class:_____

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2020

CHEMISTRY **8873/01**
Higher 1 **24 September 2020**

Paper 1 **1 hour**

Additional materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and exam index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **30** questions in this section. 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 separate Answer Sheet.

Read the instructions on the 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 booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **10** printed pages.

1 Bromine gas is toxic. The maximum safe toleration level of bromine gas in air is 4.00×10^{-6} g dm^{-3}.

How many bromine atoms are present in 1 dm^3 of air at this toleration level?

A 1.50×10^{16} **B** 3.00×10^{16}

C 6.00×10^{16} **D** 3.00×10^{19}

2 A 25 cm^3 of a 0.1 mol dm^{-3} $\mathbf{X}(NO_3)_2$ solution requires 10 cm^3 of 0.1 mol dm^{-3} of acidified potassium manganate(VII) solution for complete reaction.

What is the final oxidation state of element **X** after the reaction?

A +3

B +4

C +5

D +6

3 10 cm^3 of a pure hydrocarbon **X** was completely burnt in 80 cm^3 of excess oxygen. After cooling to room temperature, the volume of the gaseous mixture decreased to 55 cm^3. A further reduction of 40 cm^3 was observed when the residual gas was passed through sodium hydroxide.

All gas volumes were measured at the same temperature and pressure.

What is the hydrocarbon **X**?

A C_4H_8 **B** C_4H_{10} **C** C_5H_{10} **D** C_5H_{12}

4 To identify an oxide of nitrogen, 0.10 mol of the oxide is mixed with an excess of hydrogen and passed over a catalyst at a suitable temperature.

$$N_xO_y \xrightarrow[\text{catalyst}]{H_2(g)} xNH_3 + yH_2O$$

The water produced weighs 7.20 g and the ammonia produced is completely neutralised by 200 cm^3 of 1.0 mol dm^{-3} HC*l*.

What is the formula of the oxide of nitrogen?

A N_2O_4 **B** NO_2

C N_2O **D** NO

5 Disproportionation reaction occurs when an element undergoes oxidation and reduction simultaneously.

Which of the following equations describes a disproportionation reaction?

A $3ClO^- \rightarrow ClO_3^- + 2Cl^-$

B $2H_2C_2O_4 \rightarrow 2H_2O + 2C + 2CO + 2O_2$

C $2FeSO_4 \rightarrow Fe_2O_3 + SO_2 + SO_3$

D $2KMnO_4 \rightarrow MnO_2 + MnO + K_2O + 2O_2$

6 The relative atomic mass of boron, which consists of the isotopes ^{10}B and ^{11}B is 10.8.

What is the percentage of ^{11}B atoms in the isotopic mixture?

A 80 % **B** 20 %

C 0.8 % **D** 0.2 %

7 The electronic configurations of four elements are given.

Which of these elements has the highest first ionisation energy?

A $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ **B** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

C $1s^2\ 2s^2\ 2p^6\ 3s^2$ **D** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1$

8 *Use of Data Booklet is relevant to this question.*

Which of the following particles have more neutrons than protons and more electrons than neutrons?

A $^{14}NO_2^+$ **B** $^{13}CO_3^{2-}$

C $^{32}S^{2-}$ **D** $^{14}N_2^+$

9 **Z** has the following electronic configuration.

What could **Z** be?

1 Cl^+ ion

2 S atom

3 P^{3-} ion

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

10 Which of the following statements about potassium fluoride and hydrogen fluoride is true?

A They both have comparable boiling points.

B They are hard but brittle.

C They contain the same type of bonding.

D They are soluble in water.

11 Which statements are correct for the sequence of compounds below considered from left to right?

NaF MgO AlN SiC

1 The electronegativity difference between the elements in each compound increases.

2 The compounds are isoelectronic.

3 The bonding becomes increasingly covalent.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

12 Silicon carbide (carborundum) is a shiny, hard and chemically inert material with a very high melting point. It can be used to sharpen knives and make crucibles.

Which type of structure explains these properties?

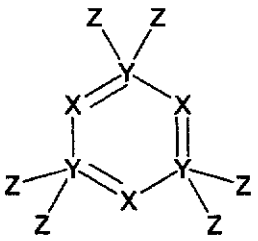
A a giant structure with covalent bonds between silicon and carbon atoms

B a giant structure containing metallic bonding

C a giant layer structure with covalent bonds between atoms and weak intermolecular forces between the layers

D a simple molecular structure with covalent bonds between the atoms of silicon and carbon

13 A stable molecule containing atoms of the elements **X**, **Y** and **Z** has the structure shown on the right.



Which of the following is a possible combination of the elements?

	X	Y	Z
A	B	N	F
B	*Al*	N	H
C	N	P	H
D	O	P	F

14 Element **Q** is from Period 3 of the Periodic Table.

Element **Q** reacts with oxygen to form a high melting point solid which is insoluble in water. When **Q** reacts with chlorine, a low melting point liquid is formed which is soluble in water, giving a solution with a pH of 1.

What is **Q**?

A magnesium **B** aluminium

C silicon **D** phosphorus

15 Which series is correctly arranged in order of increasing values?

A atomic radius of P, S, *Cl*

B ionic radius of Cl^-, S^{2-}, P^{3-}

C ionic radius of Na^+, Mg^{2+}, Al^{3+}

D melting point of *Al*, Si, P

16 In an experiment, 5.00 g of solid Na_2CO_3 was added to a polystyrene cup containing 25.0 cm^3 of 1.0 mol dm^{-3} aqueous HC*l*. It was found that the temperature of the solution rose by 4.1 °C.

The equation for the reaction is as follows.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

What is the correct value for the enthalpy change of reaction above?

(Assume that the heat capacity of the solution is 4.2 J K^{-1} cm^{-3})

A −9.13 kJ mol^{-1}

B −11.0 kJ mol^{-1}

C −17.2 kJ mol^{-1}

D −34.4 kJ mol^{-1}

17 Which of the following reactions does the value of ΔH^{θ} represent both a standard enthalpy change of combustion and a standard enthalpy change of formation?

1 $C(s) + O_2(g) \rightarrow CO_2(g)$

2 $H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g)$

3 $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$

A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

18 Gaseous phosphorus pentachloride, PCl_5, can be decomposed into gaseous phosphorus trichloride and chlorine by heating. The table below gives the bond energies.

Bond	Bond energy / kJ mol^{-1}
P-C*l* (in both chlorides)	330
C*l*-C*l*	240

What is the enthalpy change of decomposition of PCl_5?

A +90 kJ mol^{-1}

B -90 kJ mol^{-1}

C +420 kJ mol^{-1}

D -420 kJ mol^{-1}

19 The rate of reaction of a strip of magnesium ribbon in 50 cm^3 of 1.0 mol dm^{-3} H_2SO_4 is determined at 25 °C.

In which of the following cases would *both* the new conditions contribute to the increase in the rate of reaction?

A 100 cm^3 of 1.0 mol dm^{-3} H_2SO_4 at 30 °C

B 25 cm^3 of 2.0 mol dm^{-3} H_2SO_4 at 30 °C

C Mg powder and 100 cm^3 of 1.0 mol dm^{-3} H_2SO_4

D Mg powder and 50 cm^3 of 0.8 mol dm^{-3} H_2SO_4

20 The rate of decay of a radioactive isotope is a first-order reaction.

Given that the radioactivity decreased from 1200 counts per minute to 75 counts per minute in 48 hours, what is the time needed for 1200 counts to drop to 300 counts per minute?

A 8 hours

B 12 hours

C 16 hours

D 24 hours

21 For which equilibrium does K_c have no units?

A $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

B $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

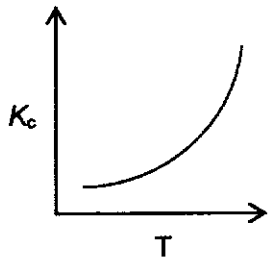
C $Cu^{2+}(aq) + 4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq)$

D $CH_3OH(l) + CH_3CO_2H(l) \rightleftharpoons CH_3CO_2CH_3(l) + H_2O(l)$

22 The equilibrium constant, K_c, for the reaction

$$X(g) + Y(g) \rightleftharpoons Z(g)$$

varies with temperature as shown in the diagram below.



Which conclusion(s) can be drawn from these information?

1 The reaction is endothermic in the forward reaction.

2 The equilibrium mixture contains a greater proportion of Z at higher temperature.

3 The equilibrium mixture contains a greater proportion of Z at higher pressure.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

23 An enzyme, found in the stomach, operates at maximum efficiency when in an aqueous solution buffered at pH 5.

Which combination of substances, when dissolved in 1 dm^3 of water, would give the necessary buffer solution?

A 2 mol of CH_3CO_2H and 1 mol of NaOH

B 1 mol of CH_3CO_2H and 2 mol of NaOH

C 1 mol of HC*l* and 1 mol of CH_3CO_2Na

D 2 mol of NH_3 and 1 mol of $CH_3CO_2NH_4$

24 20 cm^3 of 0.10 $moldm^{-3}$ of aqueous barium hydroxide, $Ba(OH)_2$ was mixed with 20 cm^3 of 0.10 $moldm^{-3}$ of aqueous hydrochloric acid. The following reaction occurs:

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$$

What is the pH of the resulting solution?

A 1.30 **B** 2.60 **C** 11.4 **D** 12.7

25 The diagram shows a reaction scheme.

$$C_2H_5Cl \xrightarrow{I} C_2H_6O \xrightarrow{II} C_2H_4$$

What types of reaction are reactions **I** and **II**?

	I	II
A	oxidation	reduction
B	substitution	reduction
C	oxidation	elimination
D	substitution	elimination

26 When 2-methylbutane was treated with limited Cl_2 under UV light, four possible constitutional isomers were formed.

Structural formulae for three of the isomers are shown.

$ClCH_2CH_2CH(CH_3)_2$ $CH_3CH(Cl)CH(CH_3)_2$ $CH_3CH_2CH(CH_3)CH_2Cl$

What is the name of the fourth isomer?

A 2-chloro-2-methylpropane

B 2-chloro-2-methylbutane

C 2-chloro-3-methylbutane

D 1-chloropentane

27 Which statements about a propene molecule are correct?

1 It has eight σ bonds and one π bond.

2 It has an empirical formula of CH_2.

3 It has all its atoms in the same plane.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

28 An ester, **X**, of molecular formula, $C_6H_{12}O_2$ undergoes acid hydrolysis to produce a carboxylic acid and an alcohol. The alcohol reacts with an acidified solution of sodium dichromate(VI) to produce a ketone.

What could be the structural formula of ester **X**?

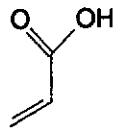
A $CH_3CH_2CH_2CO_2CH_2CH_3$

B $(CH_3)_2CHCO_2CH_2CH_3$

C $CH_3CH_2CO_2CH(CH_3)_2$

D $CH_3CO_2C(CH_3)_3$

29 The major component of 'superabsorbent' polymer (SAP) is acrylic acid which polymerises when blended with sodium hydroxide in the presence of an initiator.



acrylic acid

Which of the following statements is/are true?

1 SAP is biodegradable.

2 SAP is able to form hydrogen bonds with water.

3 There will be no loss of molecule during the polymerisation of SAP.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

30 Part of the structure of a polyamide is shown below:

$$–NH–CH(CH_3)–NHCO–CH(CH_3)–CO–$$

Which of the following statements is not true?

A It is a thermoplastic.

B The polymer chains are held together by hydrogen bonds.

C The polymer can be used to make containers to contain acids.

D The N–C–O angle in the polymer is 120°.

Name:_____ Class:_____

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2020

CHEMISTRY **8873/02**

Higher 1 **17 September 2020**

Paper 2 **2 hours**

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A (60 marks)
Answer **all** the questions in the spaces provided on the Question paper.

Section B (20 marks)
Answer **one** question in the spaces provided on the Question paper.

The use of an approved scientific calculator is expected, where appropriate.
A *Data Booklet* is provided.

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

For Examiner's Use		
Section A	1	/6
	2	/11
	3	/10
	4	/15
	5	/18
Section B	6	/20
	7	/20
Penalty (delete accordingly)		
Missing/wrong units in final answer		–1 / NA
Total		/80

This document consists of **18** printed pages.

Section A

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

For Examiner's Use

1 Artists between the 13th and 19th centuries used a green pigment called verdigris. This pigment was made by hanging copper foil over boiling vinegar.

(a) During the preparation of verdigris, copper atoms are oxidised to copper(II) ions.

$$Cu \rightarrow Cu^{2+} + 2e^-$$

(i) In the reaction, oxygen is reduced to water in acidic medium.

Construct a half equation for the reaction.

..... [1]

(ii) Construct a balanced equation for the redox reaction between copper, oxygen and hydrogen ions.

..... [1]

(iii) Given that 5 g of copper foil was boiled in vinegar to produce verdigris, calculate the volume of oxygen used in the reaction at room temperature and pressure.

[2]

(b) A sample of verdigris has the formula $[(CH_3COO)_2Cu]_2.Cu(OH)_2.xH_2O$. Analysis of 100 g of the sample shows that it contains 16.3% water by mass.

(i) Calculate the number of moles of $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ present in 100 g of the sample of verdigris.

[Given that M_r of $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ = 460.5]

[1]

(ii) Hence or otherwise, calculate the value of ***x*** in the formula.

For Examiner's Use

[1]

[Total:6]

2 Simple molecules vary in shapes and polarity.

HF	N_2	NH_3
BF_3	CO_2	H_2O

(a) State which of the molecules shown above are polar.

..... [1]

(b) Arrange the molecules identified in **(a)** in order of increasing polarity of the bond in the molecules. Explain your answer.

.....

.....

.....

..... [2]

(c) Draw dot-and-cross diagrams to show the bonding in ClF_3, SO_2 and PH_3.

Name the shapes of these molecules.

Formulae	ClF_3	SO_2	PH_3
Dot-and-cross diagram			
Name of shape			

[6]

(d) Suggest, with reference to structure and bonding, why BF_3 is a gas at room temperature.

For Examiner's Use

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.....

.....

..... [2]

[Total: 11]

3 Nitrogen was discovered in 1772 by Daniel Rutherford. It is the fifth most abundant element found on earth.

(a) **(i)** Define, with the aid of an equation, the first ionisation energy of nitrogen.

.....

.....

..... [2]

(ii) Explain why nitrogen has a higher first ionisation energy than oxygen.

.....

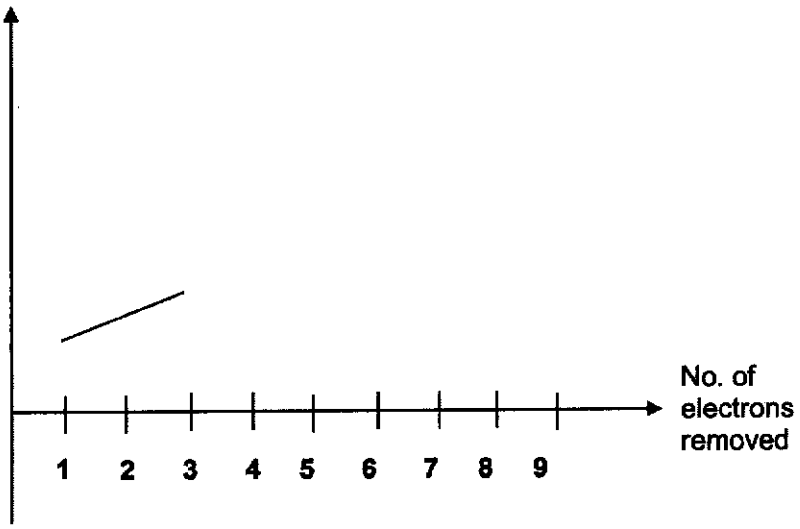
.....

.....

..... [2]

(iii) On the axes below, complete the sketch of the ionisation energies for all the electrons present in a nitrogen atom. The ionisation energies of the first three electrons are shown below.

Ionisation Energy / kJ mol^{-1}



[2]

For Examiner's Use

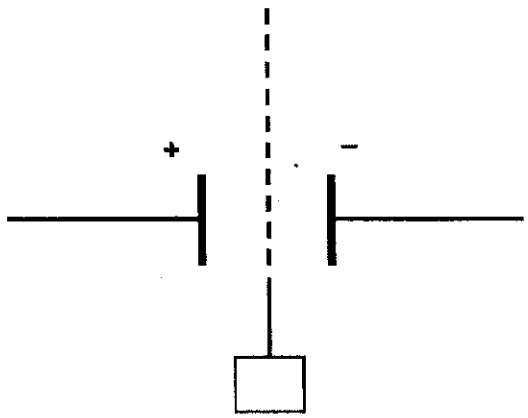
(b) Magnesium burns in nitrogen to give magnesium nitride, Mg_3N_2.

(i) Draw a dot-and-cross diagram to illustrate the bonding in Mg_3N_2.

[1]

(ii) When separate beams of $^{24}Mg^{2+}$ and $^{14}N^{3-}$ are passed through an electric field in the apparatus below, they behave differently.

Sketch on the diagram below to show the paths of the beams of $^{24}Mg^{2+}$ and $^{14}N^{3-}$ as they enter the electric field.



[2]

(iii) Given that the angle of deflection of the $^{24}Mg^{2+}$ beam is 4.0°, calculate the angle of deflection of the $^{14}N^{3-}$ beam. Give your answer to the **nearest whole number.**

[1]

[Total:10]

For Examiner's Use

4 (a) Elements **K** and **L** are in Period 3. Chloride of **K** dissolves in water to form an acidic solution (pH = 3). Both oxide and chloride of element **L** are solids which are soluble in water producing a strongly acidic solution (pH = 2).

Suggest the identities of elements **K** and **L**.

Write balanced equations for the above observations about elements **K** and **L**.

.....

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.....

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.....

..... [5]

(b) Acrylic acid, CH_2=CHCOOH, is a monobasic weak acid.

(i) Explain the meaning of *weak* acid.

.....

..... [1]

(ii) Write an equation for the dissociation of acrylic acid in water.

..... [1]

(iii) Given that a 0.0800 mol dm^{-3} of acrylic acid is 2.6% dissociated. Calculate

- pH of the solution,
- K_a of the acid.

[4]

For Examiner's Use

(iv) During titration, it was found that 25.0 cm^3 of the acid required 20.00 cm^3 of 0.10 mol dm^{-3} NaOH(aq) for complete reaction. Write a balanced equation for the reaction.

..... [1]

(v) Suggest a suitable indicator for the titration of acrylic acid with sodium hydroxide in **(iv)**.

..... [1]

(vi) Before the end-point was reached in **(iv)**, there was a mixture of acrylic acid (CH_2=$CHCO_2H$) and its salt (CH_2=$CHCO_2Na$) in the solution.

By means of ionic equations, show how this mixture of acrylic acid and its salt removes the small amounts sodium hydroxide and hydrochloric acid when added separately.

.....

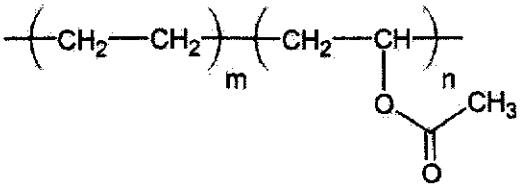
..... [2]

[Total: 15]

5 (a) Hot melt adhesive also known as hot glue, is a form of adhesive that is commonly sold as solid cylindrical sticks of various diameters designed to be applied using a hot glue gun.

For Examiner's Use

The polymer, EVA, is a copolymer which is commonly used in the hot glue.



EVA

Commonly, in an EVA polymer, there are more m units than n units. This is done to increase the viscosity of the glue.

EVA is an elastomeric polymer that produces materials which are "rubber-like" in softness and flexibility. It has good clarity and gloss, low-temperature toughness, stress-crack resistance and resistance to UV radiation. EVA has many attractive properties including low cost, excellent adhesion to many polar and nonporous substrates. It also can be recycled.

Another polymer, poly(vinyl chloride) (PVC) is used to produce PVC glue which is used to glue water pipes.

(i) Draw the structural formulae of the two monomers used to make EVA.

[2]

(ii) State the type of reaction used to make EVA.

..... [1]

(iii) State and explain whether EVA is biodegradable.

.....

.....

.....

..... [2]

(iv) Based on the structure of EVA, predict what will be the predominant bonds that hold these polymer chains together?

For Examiner's Use

.....

..... [1]

(v) Predict whether EVA is a thermosetting or a thermoplastic polymer.

Explain your answer using the information in the question and your knowledge of the structure and bonding in polymers.

.....

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..... [2]

(vi) Explain why EVA is classified as elastomer.

.....

.....

.....

..... [2]

(vii) Suggest why EVA has good adhesion to polar and non-polar substrates.

.....

.....

.....

..... [2]

(viii) State one environmental advantage of recycling EVA.

..... [1]

(ix) Explain why poly(vinyl chloride), PVC, is used to make water pipes used in the toilets. Include a diagram of a repeat unit of PVC in your answer.

For Examiner's Use

.....

..... [2]

(b) Ethanoic acid is a colourless organic liquid with a formula of CH_3COOH. It is mainly produced as a precursor to polyvinyl acetate, PVA. The following is a reaction scheme using ethanoic acid.

$$CH_3CONHCH_3 \xleftarrow{\text{II}} CH_3COOH \xrightarrow{\text{I}} CH_3CH_2OH$$

(i) State the reagents and conditions for reactions **I** and **II**.

I :.....

II: ..... [2]

(ii) State the type of reaction in reaction **I**.

..... [1]

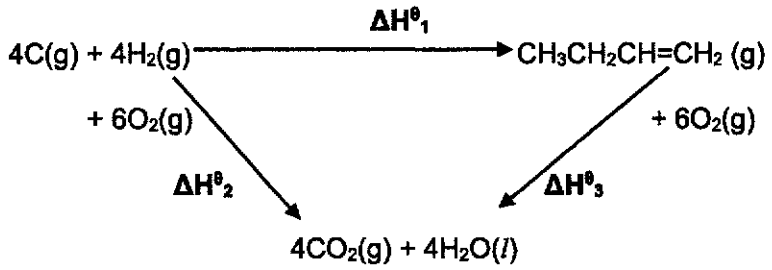
[Total: 18]

Section B

Answer **one** question from this section, in the spaces provided.

For Examiner's Use

6 **(a)** The diagram below shows an energy cycle involving but-1-ene.



Given that,
ΔH^{θ}_2 represents the standard enthalpy change of combustion for C(g) and $H_2(g)$.

ΔH^{θ}_3 represents the standard enthalpy change of combustion for $CH_3CH_2CH{=}CH_2(g)$.

(i) Define the term *bond energy*.

.....

.....

..... [1]

(ii) Using the bond energy values in the *Data Booklet*, calculate a value for ΔH^{θ}_1.

[2]

For Examiner's Use

(iii) Use the energy cycle, the following data as well as the value calculated in **(a)(ii)**, to calculate ΔH^{θ}_3.

Standard enthalpies	ΔH^{θ}/ kJ mol^{-1}
Standard enthalpy change of combustion of C(g)	–1110
Standard enthalpy change of combustion of H_2(g)	–286

[4]

(iv) The equation written in the question to represent ΔH^{θ}_1 is not correct. Explain why.

.....

.....

[1]

(v) The following experiment was done in the laboratory to find ΔH^{θ}_3.

For Examiner's Use

1.00 g of but-1-ene was burned to heat up 120 g of water. The water was heated from 30°C to 89°C. The process was known to be only 70 % efficient.

Hence, calculate the standard enthalpy change of combustion of but-1-ene, ΔH^{θ}_3.

Assume the specific heat capacity of water to be 4.3 J g^{-1} K^{-1}.

[3]

For Examiner's Use

(b) Ethyl propanoate is found naturally in apple juice, grapefruit peel and strawberries. Ethyl propanoate can be hydrolysed by aqueous NaOH.

$$C_2H_5OCOCH_2CH_3 + NaOH \rightarrow C_2H_5OH + CH_3CH_2COO^-Na^+$$

The initial rate of the hydrolysis reaction between the ester and NaOH(aq) was measured in a series of experiments at a constant temperature.

The results are obtained below:

Experiment	Initial concentration of NaOH / mol dm^{-3}	Initial concentration of ester / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.040	0.030	4.0×10^{-4}
2	0.040	0.045	6.0×10^{-4}
3	0.060	0.045	9.0×10^{-4}
4	0.120	0.060	***x***

(i) Using the data above, determine the order of reaction with respect to each reactant and hence deduce the rate equation for the reaction.

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.....

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..... [3]

(ii) Hence, otherwise, calculate the value of ***x*** in experiment 4.

.....

.....

..... [1]

(iii) Use the data from experiment 1 to calculate the rate constant, stating its units.

.....

.....

..... [2]

(c) Describe the thermal decomposition of the hydrogen halides HC*l*, HBr and HI and explain any variation in their thermal stabilities.

For Examiner's Use

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..... [3]

[Total: 20]

For Examiner's Use

7 (a) Sulfuric acid is manufactured by the Contact process. One stage in this process is the conversion of sulfur dioxide into sulfur trioxide in the presence of a heterogeneous catalyst of vanadium(V) oxide, V_2O_5.

(i) State the meaning of the term heterogeneous as applied to catalysts.

..... [1]

(ii) Heterogeneous metal catalysts, such as rhodium and platinum are used in catalytic converters in cars. Write two equations to illustrate how NO and CO gases produced in car engines, are removed by catalytic converters.

.....

..... [2]

(b) The equation for this stage of the Contact Process is shown.

$$2SO_2(g) + O_2(g) \ll 2SO_3(g) \qquad \Delta H = -196\ kJmol^{-1}$$

(i) With the help of a suitable diagram, explain why a decrease in temperature decreases the rate of production of SO_3.

.....

.....

.....

..... [3]

(ii) State and explain the effect of increasing pressure on the yield of SO_3.

.....

.....

.....

..... [2]

For Examiner's Use

(c) Another element in the third period is silicon. Similar to sulfur, silicon reacts with oxygen to form silicon dioxide which reacts with hot, concentrated sodium hydroxide.

(i) State the silicon containing product formed during the reaction between silicon dioxide and concentrated sodium hydroxide.

..... [1]

(ii) Describe the behaviour of the silicon dioxide during this reaction.

..... [1]

(d) Sodium burns in oxygen to form Na_2O.

(i) Which one of the two oppositely charged ions present in Na_2O would have a smaller ionic radius? Explain your answer.

.....

.....

.....

..... [2]

(ii) State and explain the difference in the melting points of Na_2O and MgO.

.....

.....

.....

.....

.....

..... [3]

(e) **(i)** Explain why Group 1 elements are generally good reducing agents.

.....

.....

..... [1]

For Examiner's Use

(ii) Explain why the reducing power of sodium is higher than that of lithium. Quote relevant values from the *Data Booklet* to support your answer.

.....

.....

.....

.....

.....

..... [2]

(f) When aqueous chlorine was added to a bromide solution, an orange solution, $Br_2(aq)$ was formed. However, when aqueous bromine was added to a chloride solution, no reaction occurred.

$$Cl_2(aq) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq) \quad \ldots\ldots(1)$$

$$Br_2(aq) + 2Cl^-(aq) \rightarrow \text{no reaction} \quad \ldots\ldots\ldots(2)$$

(i) State the role of $Cl_2(aq)$ in equation (1).

..... [1]

(ii) Explain why there is no reaction in equation (2) while reaction proceeds in equation (1).

.....

.....

..... [1]

[Total: 20]

Suggested Worked Solution for 2020 JPJC H1 Chem Prelim Paper 1

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

1 **Answer: B**

Amount of Br gas in 1 dm^3 = 4.00×10^{-6} / 159.8

= 2.503×10^{-8} mol

No of Br atoms in 1 dm^3 = $2.503 \times 10^{-8} \times 2 \times 6.02 \times 10^{23}$

= 3.00×10^{16}

2 **Answer: B**

Amount of $X(NO_3)_2$ = 2.50×10^{-3} mol

Amount of MnO_4^- = 1.0×10^{-3} mol

Amount of electrons taken in by MnO_4^- = $1.0 \times 10^{-3} \times 5$

= 5.0×10^{-3} mol

X^{2+} : e

$2.50 \times 10^{-3} : 5.0 \times 10^{-3}$

1 : 2

1 mol of $X(NO_3)_2$ gives away 2 mol of electrons, hence its X^{4+}

3 **Answer: B**

$$C_xH_y(g) + \left(x+\frac{y}{4}\right)O_2(g) \rightarrow xCO_2(g) + \frac{y}{2}H_2O(l)$$

Initial volume/ cm^3	10		80		–	–
Final remaining volume / cm^3	0		15		40	–
Reacting volume/ cm^3	10		65		40	–
Mole ratio	1	:	6.5	:	4	–

Hence, $x = 4$; $(4 + \frac{y}{4}) = 6.5$ and $\therefore y = 10$

Molecular formula of the hydrocarbon is C_4H_{10}.

4 **Answer: A**

Amount of H_2O = 0.400 mol ⟶ Amount of O = 0.400mol

Amount of HCl = 0.200 mol

1 mol of NH_3 reacts with 1 mol of HCl – Amount of N = 0.200mol

N_xO_y : N : O

0.10 : 0.20 : 0.40

1 : 2 : 4

Formula = N_2O_4

5 **Answer: A**

A **disproportionation reaction** is a redox reaction in which one particular element in a molecule, atom or ion is simultaneously oxidised and reduced.

$3ClO^- \rightarrow ClO_3^- + 2Cl^-$

O.N. +1 +5 -1

The Cl is oxidised and reduced simultaneously.

6 **Answer: A**

Let y be the % of B^{11} isotope.

$$\frac{y}{100} x11 + \left(\frac{100-y}{100}\right) x10 = 10.8$$

y= 80 %

7 **Answer: A**

Option A has higher nuclear charge than Option B with the same no of quantum shells. Option B has inter-electronic repulsion in $3p^4$ hence would have lower IE than Option A. Option D has an extra quantum shell of electrons compared to options A,B and C, hence it would have the lower first IE than Option A.

8 **Answer: B**

Particles	Neutrons	Protons	Electrons
NO_2^+	23	23	24
[redacted]	[redacted]	[redacted]	[redacted]
$^{32}S^{2-}$	16	16	18
$^{14}N_2^+$	14	14	13

9 **Answer: B**

Cl^- ion $1s^2 2s^2 2p^6 3s^2 3p^4$ } These are correct answers

S atom $1s^2 2s^2 2p^6 3s^2 3p^4$ }

P^{3-} ion $1s^2 2s^2 2p^6 3s^2 3p^6$ ×

10 **Answer: D**

×**A** KF is an ionic compound with strong ionic bonds between the ions while HF is a simple covalent compound with hydrogen bonds between the molecules. So KF has higher boiling pt than HF

×**B** HF is a gas while KF is hard and brittle.

×**C** KF is an ionic compound with giant ionic lattice structure while HF is a simple covalent compound with simple molecular structure.

✓**D** Both are soluble as HF forms favourable hydrogen bonds with the water molecules while KF forms ion dipole interactions with the water molecules.

11 **Answer: C**

×**1.** The electronegativity difference between the elements decreases as the compounds are from ionic to covalent from left to right.

✓**2.** Isoelectronic means atoms, ions or molecules containing same number of electrons. The no of electrons in each compound is 18.

✓**3.** The electronegativity difference between the elements decreases so the compounds became more covalent from left to right.

12 **Answer: A**

✓**A** This description fits silicon carbide (SiC) as it hard and can be used to sharpen knives and make crucible. SiC is a giant covalent compound.

×**B** Silicon and C are not metals and hence its not metallic structure in SiC.

×**C** SiC is used to sharpen knoves and hence cannot have weak intermolecular forces between layers.

×**D** SiC has high melting point and its hard. So simple molecular structure do not fit the description for SiC.

13 **Answer: C**

X has 1 double bond and 1 single bond. It must have one lp of electrons on it. So it must be from Group 15. X must be N.

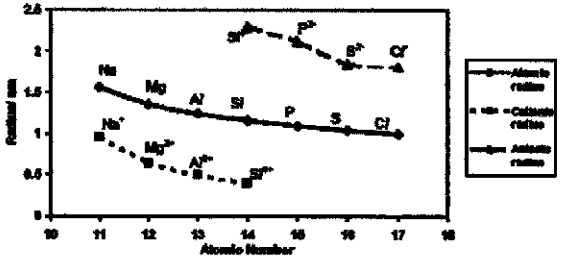
Y has 3 single bonds and 1 double bond. It must be from Group 15 and must be from Period 3 and above as it can expand octet upon bonding. Y must be P

Z forms on single bond. So it could be a H or F.

14 **Answer: C**

Oxide **Q** is insoluble in water which means it could be SiO_2 or Al_2O_3. **Q** reacts with chlorine to give a low melting point liquid which filts $SiCl_4$ (non polar simple covalent cpd) and it does hydrolyse completely in water to give strong acid, HCl. $AlCl_3$ only partially hydrolyses in water to give a solution of pH 3.

15 **Answer: B**



The anionic radius decreases from Si^{4-} to Cl^- (Electronic configuration: [redacted])

Similarly for the anions (Si^{4-}, P^{3-}, S^{2-} and Cl^-) are isoelectronic (constant shielding). The decrease in anionic radii is also due to the increase in nuclear charge. So the reverse order of Cl^- to P^{3-} is an increase in the radius.

Option D – Si has the highest melting point in Period 3. So the increasing order of melting pt from Al to P is wrong.

16 **Answer: D**

Amount of Na_2CO_3 = 5/106 = 0.04712 mol

Amount of HCl = 0.0250 mol

HCl is the limiting reagent.

$$\Delta H^\theta = \frac{\pm q}{\text{amount of LR}} \times \text{Stoichiometric Coefficient of LR}$$

$$= \frac{-25 \times 4.2 \times 4.1}{0.0250} \times 2$$

$= -34.4 kJ\ mol^{-1}$

17 **Answer: D**

Standard enthalpy change of formation is the heat energy change when **one mole of a compound** is formed from its constituent elements in their standard states under standard conditions of 298 K and 1 bar.

Standard enthalpy change of combustion is the heat energy evolved when **one mole of a substance is completely burnt in oxygen** under standard conditions of 298 K and 1 ba

✓1 $C(s) + O_2(g) \rightarrow CO_2(g)$

×2 $H_2(g) + ½ O_2(g) \rightarrow H_2O(g)$ (H_2O must be in liquid state at 298K)

×3 $N_2(g) + 2O_2(g) \rightarrow 2NO_2(g)$ (Not 1 mole of cpd formed)

18 **Answer: C**

$$PCl_5 \rightarrow PCl_3 + Cl_2$$

ΔH = ΣmBE(bond broken) - ΣnBE(bond formed)
= ΣmBE(reactants) - ΣnBE(products)
= (5x330) – [(3x330) + 240]
= +420 kJ/mol

19 **Answer: B**

×A 100cm³ of 1.0 moldm⁻³ will not increase the rate as the conc is the same.

✓B The conc increased and also the temp. Thus, both conditions will increase the rate.

×C Mg powder will increase the rate (due to larger surface area for reaction) but the conc of HCl is the same. So both conditions will not increase the rate

×D Mg powder will increase the rate (due to larger surface area for reaction) but the conc of HCl is lower than 1 moldm⁻³. So both conditions will not increase the rate

20 **Answer: D**

First order reactions means the half life is constant.

1200 → 600→300→150→75

4 ($t_{1/2}$) = 48hrs

$t_{1/2}$ = 12hrs

for 1200 counts to drop to 300 counts need 2 $t_{1/2}$. Hence, 2 x 12 = 24hrs

21 **Answer: D**

Only D has no units

Equations	Equilibrium Constant Expression	Units
$N_2O_4(g) \quad 2NO_2(g)$	$K_c = \frac{[NO_2]^2}{[N_2O_4]}$	mol dm⁻³
$C(s)+H_2O(g) \rightleftharpoons CO(g)+H_2(g)$	$K_c = \frac{[CO][H_2]}{[H_2O]}$	mol dm⁻³
$Cu^{2+}(aq)+4NH_3(aq) \rightleftharpoons [Cu(NH_3)_4]^{2+}(aq)$	$K_c = \frac{[Cu(NH_3)_4]^{2+}}{[Cu^{2+}][NH_3]^4}$	mol⁻⁴dm¹²

22 **Answer: A**

✓1 According to the graph, K_c increases when temp increases. According to LCP, when temp increases, endothermic reaction is favoured. Hence the forward reaction is endothermic.

✓2 At higher temperature, endothermic reaction is favoured. Hence, forward reaction is favoured. Therefore, there is a greater proportion of Z.

✓3 At higher pressure, the eqm shifts to the side that has lesser amount of gases in the system. Hence, the eqm shifts to the right and hence there will be there is a greater proportion of Z in the eqm mixture.

23 **Answer: A**

The buffer at pH 5 is an acidic buffer which is made up of a weak acid and its salt.

✓A Mixture of a weak acid and its salt, $CH_3COO^-Na^+$

×B Mixture of NaOH (strong base) and $CH_3COO^-Na^+$

×C Mixture of a strong acid and some salt.

×D This is an alkaline buffer. Weak base and its salt.

24 **Answer: D**

$$Ba(OH)_2(aq) + 2HCl(aq) \rightarrow BaCl_2(aq) + 2H_2O(l)$$

Amount of $Ba(OH)_2$ = 2.00 x 10⁻³ mol

Amount of HCl = 2.00 x 10⁻³ mol

Amount of $Ba(OH)_2$ in excess = 1.00 x 10⁻³ mol

Amount of OH^- = 2 x 1.00 x 10⁻³ = 2.00 x 10⁻³ mol

$$[OH^-] = = \frac{0.00200}{\frac{40}{1000}} = 0.05$$

pOH = 1.30

pH = 14 -1.3 = 12.7

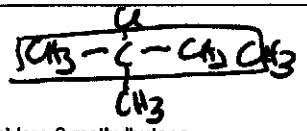
25 **Answer: D**

$$C_2H_5Cl \xrightarrow{I} C_2H_6O \xrightarrow{II} C_2H_4$$

Step 1 involves the substitution of Cl by OH.

Step 2 is the elimination of water from C_2H_6O (alcohol) to C_2H_4 (alkene).

26 **Answer: B**

Fourth Isomer : 

The name is 2-chloro-2-methylbutane.

27 **Answer: B**

✓1 $CH_3CH=CH_2$ has eight σ bonds and one π bond.

✓2 C_3H_6 is the molecular formula for propene and the simplest ratio of the elements will be CH_2.

×3 It has a C in the CH_3 in the $CH_3CH=CH_2$ that is tetrahedral in shape. So not all atoms are are on the same plane.

28 **Answer: C**

The alcohol produced must be a 2° alcohol which will then be oxidised to ketone.

×A	The products after hydrolysis are $CH_3CH_2CH_2COOH$ + CH_3CH_2OH (1° alcohol)
×B	The products after hydrolysis are $(CH_3)_2CHCOOH$ + CH_3CH_2OH (1° alcohol)
✓C	The products after hydrolysis are CH_3CH_2COOH + $(CH_3)_2CH(OH)$ (2° alcohol)

	✗D	The products after hydrolysis are CH_3COOH + $(CH_3)_3C(OH)$ (3° alcohol which cannot be oxidised)

29 **Answer: C**

✗1 SAP is not biodegradable it has no ester or amide linkages to be hydrolysed by acids or bases and the C-C bonds in the polymer is non-polar and thus inert.

✓2 SAP has -COOH group in the polymer which can form hydrogen bonds with water.

✓3 Since this polymer is made from addition polymerisation, there is no loss of any portion of the monomer.

30 **Answer: C**

✗A	The polyamide is a linear polymers with no cross linkages so it is classified as a thermoplastic.
✗B	The amide linkages in the polymer is capable of forming hydrogen bonds with another amide linkages in the polymer.
✓C	The polymer has amide linkages and hence the containers cannot contain acid as it will hydrolyse the amide bonds.
✗D	The C has 3 bond pairs and 0 lone pairs around it in N-C-O. Hence, it's a trigonal planar geometry around the C atom so its 120°.

Name:_____ Class:_____

JURONG PIONEER JUNIOR COLLEGE

JC2 Preliminary Examination 2020

CHEMISTRY **8873/02**

Higher 1 **17 September 2020**

Paper 2 **2 hours**

Additional materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, class and exam index number on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A (60 marks)
Answer **all** the questions in the spaces provided on the Question paper.

Section B (20 marks)
Answer **one** question in the spaces provided on the Question paper.

The use of an approved scientific calculator is expected, where appropriate.
A *Data Booklet* is provided.

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

For Examiner's Use		
Section A	1	/6
	2	/11
	3	/10
	4	/15
	5	/18
Section B	6	/20
	7	/20
Penalty (delete accordingly)		
Missing/wrong units in final answer		–1 / NA
Total		/80

This document consists of **18** printed pages and **0** blank pages.

Section A

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

1 Artists between the 13th and 19th centuries used a green pigment called verdigris. This pigment was made by hanging copper foil over boiling vinegar.

For Examiner's Use

(a) During the preparation of verdigris, copper atoms are oxidised to copper(II) ions.

$$Cu \rightarrow Cu^{2+} + 2e^-$$

(i) In the reaction, oxygen is reduced to water in acidic medium.

Construct a half equation for the reaction.

$O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ **[1m]**, state symbols not required [1]

(ii) Construct a balanced equation for the redox reaction between copper, oxygen and hydrogen ions.

$2Cu + O_2 + 4H^+ \rightarrow 2Cu^{2+} + 2H_2O$ **[1m]**, state symbols not required [1]

(iii) Given that 5 g of copper foil was boiled in vinegar to produce verdigris, calculate the volume of oxygen used in the reaction at room temperature and pressure.

Amount of copper foil used = $\frac{5}{63.5}$ = 0.07874 mol

Since $2Cu \equiv O_2$,

Amount of O_2 used in the reaction = $\frac{1}{2} \times$ **0.0787** **[1m]** working, awarded only if amt of Cu is correctly calculated

= 0.03937 mol

Volume of O_2 used in the reaction at room temperature and pressure

= 0.0394 × 24 = **0.945 dm³** or **945 cm³** **[1m]** 3sf, ecf from amount of O_2 used and units [2]

(b) A sample of verdigris has the formula $[(CH_3COO)_2Cu]_2.Cu(OH)_2.xH_2O$. Analysis of 100 g of the sample shows that it contains 16.3% water by mass.

(i) Calculate the number of moles of $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ present in 100 g of the sample of verdigris.

[Given that M_r of $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ = 460.5]

M_r of $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ = 460.5

Amount of $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ = $\frac{100 - 16.3}{460.5}$

= 0.1818 mol **[1m] working**

[1]

(ii) Hence or otherwise, calculate the value of x in the formula.

Amount of water present = $\frac{16.3}{18.0}$ = 0.9055 mol

	$[(CH_3COO)_2Cu]_2.Cu(OH)_2$	H_2O
Amount/mol	0.182	0.9055
Ratio	1	4.98 ≈ 5

The value of x is **5**.

[1m] comparing mole ratio between $[(CH_3COO)_2Cu]_2.Cu(OH)_2$ and H_2O.

ecf ans from (b)(i) [1]

[Total:6]

2 Simple molecules vary in shapes and polarity.

For Examiner's Use

HF	N_2	NH_3
BF_3	CO_2	H_2O

(a) State which of the molecules shown above are polar.

HF, NH_3, H_2O [1m] [1]

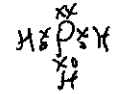
(b) Arrange the molecules identified in **(a)** in order of increasing polarity of the bond in the molecules. Explain your answer.

Bond polarity: $NH_3 < H_2O < HF$ [1m]

F/Fluorine is the most electronegative atom, followed by O/oxygen, then N/nitrogen. OR electronegativity: F > O > N [1m] [2]

(c) Draw dot-and-cross diagrams to show the bonding in ClF_3, SO_2 and PH_3.

Name the shapes of these molecules.

Formulae	ClF_3	SO_2	PH_3
Dot-and-cross diagram	[1m] 	[1m] 	[1m]
Name of shape	T-shaped [1m]	V-shaped/bent [1m]	trigonal pyramidal [1m]

[6]

(d) Suggest, with reference to structure and bonding, why BF_3 is a gas at room temperature.

BF_3 has a simple molecular structure. [1m] It has weak intermolecular forces/ instantaneous dipole-induced dipole forces between the molecules. [1m] Hence, it's a gas at room temperature. [2]

[Total: 11]

[Turn over

3 Nitrogen was discovered in 1772 by Daniel Rutherford. It is the fifth most abundant element found on earth.

For Examiner's Use

(a) (i) Define, with the aid of an equation, the first ionisation energy of nitrogen.

The first ionisation energy of nitrogen is the energy required to remove one mole of electrons from one mole of gaseous nitrogen atoms to form one mole of gaseous singly positively charged ions. [1m]

$N(g) \rightarrow N^+(g) + e^-$ [1m] [2]

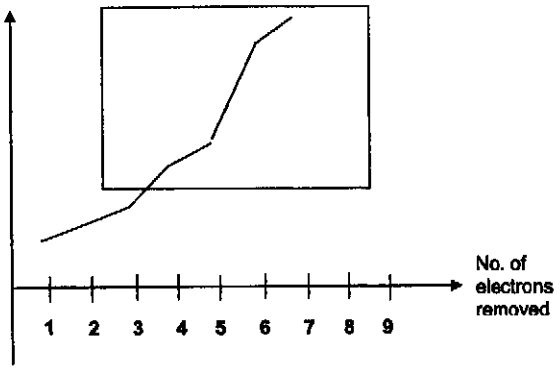
(ii) Explain why nitrogen has a higher first ionisation energy than oxygen.

Interelectronic reoulsion / mutual repulsion between the paired 2p electrons in oxygen [1] makes it easier to remove (or lesser energy is required to remove) [1] one of the 2p paired electrons than to remove the unpaired 2p electron from nitrogen. [2]

(iii) On the axes below, complete the sketch of the ionisation energies for all the electrons present in a nitrogen atom. The ionisation energies of the first three electrons are show below.

[1m]: moderate increase between 3rd and 4th electrons

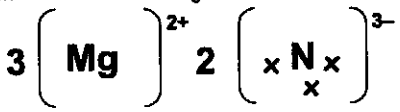
[1m]: large increase between 5th and 6th electron and 7 electrons for N.



[2]

(b) Magnesium burns in nitrogen to give magnesium nitride, Mg_3N_2.

(i) Draw a dot-and-cross diagram to illustrate the bonding in Mg_3N_2.



[1m] Mg with correct charge on Mg^{2+}

[1m] correct no. of dots and crosses around N with correct charge on N^{3-}

[1]

(ii) When separate beams of $^{24}Mg^{2+}$ and $^{14}N^{3-}$ are passed through an electric field in the apparatus below, they behave differently.

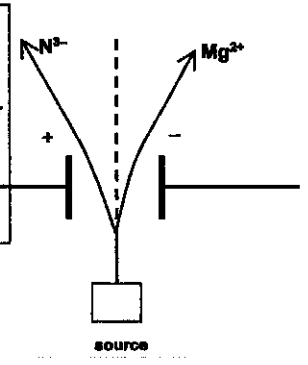
Sketch on the diagram below to show the paths of the beams of $^{24}Mg^{2+}$ and $^{14}N^{3-}$ as they enter the electric field.

[1m] for each beam

Note:

(i) Mg^{2+} is deflected towards negative plate and extent of deflection is lesser than that of N^{3-}. N^{3-} deflected towards positive plate.

(ii) Beams of Mg^{2+} and N^{3-} to start deflecting once they enter electric field.



[2]

(iv) Given that the angle of deflection of the $^{24}Mg^{2+}$ beam is 4.0°, calculate the angle of deflection of the $^{14}N^{3-}$ beam. Give your answer to the **nearest whole number**.

Angle of deflection $\alpha \frac{\text{charge}}{\text{mass}}$ ratio

$\frac{\text{charge}}{\text{mass}}$ for $Mg^{2+} = \frac{2}{24} = 0.0833$

$\frac{\text{charge}}{\text{mass}}$ for $N^{3-} = \frac{3}{14} = 0.214$

Angle of deflection for $N^{3-} = \frac{4.0}{0.0833} \times 0.214 =$ 10° (to nearest whole number) **[1m]** [1]

[Total:10]

4 (a) Elements K and L are in Period 3. Chloride of K dissolves in water to form an acidic solution (pH = 3). Both oxide and chloride of element L are solids which are soluble in water producing a strongly acidic solution (pH = 2).

Suggest the identities of elements K and L.

Write balanced equations for the above observations about elements K and L.

Element K is Al....[1]

Dissolving:
$AlCl_3(s) + 6\ H_2O(l) \rightarrow [Al(H_2O)_6]^{3+}(aq) + 3\ Cl^-(aq)$

Hydrolysis:
$[Al(H_2O)_6]^{3+}(aq) \rightarrow [Al(H_2O)_5(OH)]^{2+}(aq) + H^+(aq)$.....[1]

[5]

Element L is P....[1]
$P_4O_{10}(s) + 6\ H_2O(l) \rightarrow 4\ H_3PO_4(aq)$...[1]
$PCl_5(s) + 4\ H_2O(l) \rightarrow H_3PO_4(aq) + 5\ HCl(aq)$[1]

(b) Acrylic acid, CH_2=CHCOOH, is a monobasic weak acid.

(i) Explain the meaning of *weak* acid.

A weak acid is a proton donor that dissociates partially. [1]

[1]

(ii) Write an equation for the dissociation of acrylic acid in water.

CH_2=CHCOOH + H_2O ⇌ CH_2=CHCOO$^-$ + H_3O^+

[1]

(iii) Given that a 0.0800 mol dm^{-3} of acrylic acid is 2.6% dissociated. Calculate
- pH of the solution,
- K_a of the acid.

$[H^+] = 2.6/100 \times 0.080 = 2.08 \times 10^{-3}$ mol dm^{-3} [1]
pH = – lg $[H^+]$ = – lg (2.08×10^{-3}) = 2.68 [1]

[1] for table

Equation	HA(aq) ⇌	H^+(aq) +	A^-(aq)
Initial [ ] / mol dm^{-3}	0.0800	0	0
Change in [ ] / mol dm^{-3}	-2.08×10^{-3}	$+2.08 \times 10^{-3}$	$+2.08 \times 10^{-3}$
Equilibrium [ ] / mol dm^{-3}	0.0800	2.08×10^{-3}	2.08×10^{-3}

Since HA is a weak acid only a small concentration is dissociated,
$[HA]_{eqm} \approx [HA]_{initial}$ = 0.0800 mol dm^{-3}

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$= = \frac{(2.08 \times 10^{-3})^2}{0.0800} = 5.41 \times 10^{-5} \text{ mol dm}^{-3}$$ [1]

[4]

(iv) During titration, it was found that 25.0 cm^3 of the acid required 20.00 cm^3 of 0.10 mol dm^{-3} NaOH(aq) for complete reaction. Write a balanced equation for the reaction.

CH_2=CHCO$_2$H + NaOH → CH_2=CHCO$_2$Na$^+$ + H_2O

[1]

(v) Suggest a suitable indicator for the titration of acrylic acid with sodium hydroxide in (iv).

[1]

Phenolphthalein [1]

(vi) Before the end-point was reached in (iv), there was a mixture of acrylic acid (CH_2=CHCO$_2$H) and its salt (CH_2=CHCO$_2$Na) in the solution.

By means of ionic equations, show how this mixture of acrylic acid and its salt removes the small amounts sodium hydroxide and hydrochloric acid when added separately.

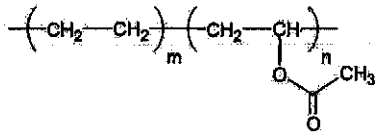
[2]

CH_2=CHCO$_2$H + OH$^-$ → CH_2=CHCO$_2^-$ + H_2O [1]
CH_2=CHCO$_2^-$ + H^+ → CH_2=CHCO$_2$H [1]

[Total: 15]

5 (a) Hot melt adhesive also known as hot glue, is a form of adhesive that is commonly sold as solid cylindrical sticks of various diameters designed to be applied using a hot glue gun.

The polymer, EVA, is a copolymer which is commonly used in the hot glue.



EVA

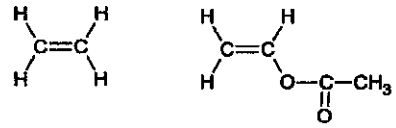
Commonly, in an EVA polymer, there are more m units than n units. This is done to increase the viscosity of the glue.

EVA is an elastomeric polymer that produces materials which are "rubber-like" in softness and flexibility. It has good clarity and gloss, low-temperature toughness, stress-crack resistance and resistance to UV radiation. EVA has many attractive properties including low cost, excellent adhesion to many polar and nonporous substrates. It also can be recycled.

Another polymer, poly(vinyl chloride) (PVC) is used to produce PVC glue which is used to glue water pipes.

(i) Draw the structural formulae of the two monomers used to make EVA.

B
M



[2]

(ii) State the type of reaction used to make EVA.

Addition polymerisation.

[1]

(iii) State and explain whether EVA is biodegradable.

EVA is non-biodegradable. [1] EVA has no ester or amide linkages [2]

[Turn over

and the C-C bonds in the polymer is non-polar and thus inert.[1]

(iv) Based on the structure of EVA, predict what will be the predominant bonds that hold these polymer chains together?

Instantaneous dipole induced dipole forces of attractions between the polymer chains since there are more m units which are non polar. [1]

(v) Predict whether EVA is a thermosetting or a thermoplastic polymer.

Explain your answer using the information in the question and your knowledge of the structure and bonding in polymers.

Thermoplastic polymer [1]. The side chains of PHBV are inert and may not react to form cross-links. In addition, cross-linking would hold the polymer chains in place becoming permanently rigid. Heating would not be able to melt it and thus cannot be recycled.[1] [2]

(vi) Explain why EVA is classified as elastomer.

EVA chains are held together by weak instantaneous dipole – induced dipole forces. Due to weak forces,[1] the polymers can be easily stretched on applying small stress and they regain their original shape when the stress is removed.[1]

This is due to the presence of no 'cross-links' between the chains, which help the polymer to retract to its original position after the force is removed. [2]

(vii) Suggest why EVA has good adhesion to polar and non-polar substrates.

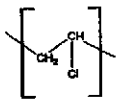
EVA has polar monomer which has an ester linkage which is polar.[1] So it is able to form bonds with polar substrates. It also have non-polar ethene monomer which can form instantaneous dipole induced dipole [1] forces of attraction with the non-polar substrates. [2]

(viii) State one environmental advantage of recycling EVA.

- Less environmental impact by reducing the amount of waste produced
- Conserves valuable oil-based resources, due to supply and cost

[any one of the answers is accepted.] [1]

(ix) Explain why poly(vinyl chloride), PVC, is used to make water pipes used in the toilets. Include a diagram of a repeat unit of PVC in your answer.



[1]

[2]

PVC is hard and insoluble in water and resistant to chemicals. Since, PVC cannot form hydrogen bonds with water, it can be used to make the water pipes. [1]

[Either one of the underlined points will be credited as 1 mk]

(b) Ethanoic acid is a colourless organic liquid with a formula of CH_3COOH. It is mainly produced as a precursor to polyvinyl acetate, PVA. The following is a reaction scheme using ethanoic acid.

$$CH_3CONHCH_3 \xleftarrow{\text{II}} CH_3COOH \xrightarrow{\text{I}} CH_3CH_2OH$$

(i) State the reagents and conditions for reactions **I** and **II**.

I : $LiAlH_4$ in dry ether
II: CH_3NH_2, DCC [2]

(ii) State the type of reaction in reaction **I**.

Reduction [1]

[Total: 18]

Section B

Answer **one** question from this section, in the spaces provided.

6 **(a)** The diagram below shows an energy cycle involving but-1-ene.

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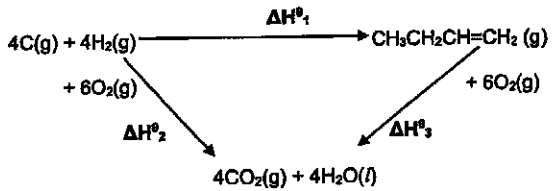


Given that:
ΔH^{θ}_2 represents the standard enthalpy change of combustion for C(g) and $H_2(g)$.

ΔH^{θ}_3 represents the standard enthalpy change of combustion for $CH_3CH_2CH=CH_2(g)$.

(i) Define the term *bond energy*.

Bond energy is the heat energy absorbed to break one mole of covalent bonds between atoms in gaseous molecules to give gaseous atoms or gaseous molecules. [1]

(ii) Using the bond energy values in the *Data Booklet*, calculate a value for ΔH^{θ}_1.

$\Delta H^{\theta}_1 = \sum mBE(\text{ reactants }) - \sum nBE(\text{ products})$
$= 4(436) - [2BE(C\text{-}C) + 8BE(C\text{-}H) + BE(C=C)]$
$= [1744] - [2(350) + 8(410) + 610]$
$= -2846$
$= -2850\ kJ\ mol^{-1}$ (2 marks) (wrong sign = no marks)
(wrong units minus 1 mark) [2]

(iii) Use the energy cycle, the following data as well as the value calculated in **(a)(ii)**, to calculate ΔH^{θ}_3.

Standard enthalpies	ΔH/ kJ mol^{-1}
Standard enthalpy change of combustion of C(g)	–1110
Standard enthalpy change of combustion of $H_2(g)$	–286

$\Delta H^{\theta}_3 = \Delta H^{\theta}_c$(but-1-ene)

$\Delta H^{\theta}_2 = [4(\Delta H^{\theta}_c(\text{ C(g) }) + 4\ \Delta H^{\theta}_c(\text{ } H_2\text{ })]$
$= 4(-1110) + 4(-286)$.....[1]
$= -5584\ kJ\ mol^{-1}$ [1]

By Hess' law
$\Delta H^{\theta}_1 + \Delta H^{\theta}_3 = \Delta H^{\theta}_2$

$\Delta H^{\theta}_3 = \Delta H^{\theta}_c$(but-1-ene)
$= \Delta H^{\theta}_2 - \Delta H^{\theta}_1$
$= -5584 - (-2846)$ ...[1] [4]

$= -2738$
$= -2740\ kJ\ mol^{-1}$ [1]

[Allow ecf if ΔH^{θ}_2 is wrongly calculated]

(iv) The equation written in the question to represent ΔH^{θ}_1 is not correct. Explain why.

Graphite/diamond exists as solid under standard conditions of 298 K and 1 bar but the graphite/diamond shown in the question is in the gaseous state. (1 mark) [1]

(v) The following experiment was done in the laboratory to find ΔH^{θ}_3.

1.00 g of but-1-ene was burned to heat up 120 g of water. The water was heated from 30°C to 89°C. The process was known to be only 70 % efficient.

Hence, calculate the standard enthalpy change of combustion of but-1-ene, ΔH^{θ}_3.

Assume the specific heat capacity of water to be $4.3\ J\ g^{-1}\ K^{-1}$.

Heat gained by 100 g of water
$= 120 \times 4.3 \times (89 - 30)$
$= 30444\ J = 30.444\ kJ$ [1]

$$\Delta H^{\theta}_c = \frac{-q}{\text{n(substance burnt)}}$$
$= [30.444/70 \times 100] / (1/56)$ [1]
$= -2440\ kJ\ mol^{-1}$ [1] [3]

(b) Ethyl propanoate is found naturally in apple juice, grapefruit peel and strawberries. Ethyl propanoate can be hydrolysed by aqueous NaOH.

$$C_2H_5OCOCH_2CH_3 + NaOH \rightarrow C_2H_5OH + CH_3CH_2COO^-Na^+$$

The initial rate of the hydrolysis reaction between the ester and NaOH(aq) was measured in a series of experiments at a constant temperature. The results are obtained below:

Experiment	Initial concentration of NaOH / mol dm^{-3}	Initial concentration of ester / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.040	0.030	4.0×10^{-4}
2	0.040	0.045	6.0×10^{-4}
3	0.060	0.045	9.0×10^{-4}
4	0.120	0.060	x

(i) Using the data above, determine the order of reaction with respect to each reactant and hence deduce the rate equation for the reaction.

By inspection, using experiments 1 and 2, when [NaOH] is constant and [ester] increases by 1.5 times, initial rate increases by 1.5 times. Hence, order with respect to ester is 1. [1]

By inspection, using experiments 2 and 3, when [ester] is constant and [NaOH] increases by 1.5 times, initial rate increases by 1.5 times. [3]

[Turn over

Hence, order with respect to NaOH is 1. [1]

Rate = k[ester][NaOH] [1]

(ii) Hence, otherwise, calculate the value of *x* in experiment 4.

Using expts 1 and 4, $x = (3 \times 2 \times 4.0 \times 10^{-4})$
$= \underline{2.40 \times 10^{-3}}$ mol dm^{-3} s^{-1} [1]

[1]

(iii) Use the data from experiment 1 to calculate the rate constant, stating its units.

Using expt 1,
$4.0 \times 10^{-4} = k\,(0.04)(0.03)$
$k = 0.333$ mol^{-1}dm^{3}s^{-1} [1 for value, 1 for units]

[2]

(c) Describe the thermal decomposition of the hydrogen halides HC*l*, HBr and HI and explain any variation in their thermal stabilities.

The thermal decomposition of the hydrogen halides involves the breaking of the covalent bond between the H atom and the halogen atom. [1]

$2HX(g) \rightarrow H_2(g) + X_2(g)$..... or show the eqn

The thermal stability of Group 17 hydrides decreases. [1] down the group. Down the group, the atomic radii of the halogen increases, which resulted in the less effective overlap due to the bigger orbitals involved.
The H-X bond length increases thus the H-X bond strength weakens down the group, resulting in lesser energy required to break the weaker H-X bond for decomposition and the thermal stability decreases.
[3 marking points – 1mk]
[Use of bond energy data to explain the thermal decomposition is also accepted – 1mk]

[3]

[Total: 20]

7 **(a)** Sulfuric acid is manufactured by the Contact process. One stage in this process is the conversion of sulfur dioxide into sulfur trioxide in the presence of a heterogeneous catalyst of vanadium(V) oxide, V_2O_5.

(i) State the meaning of the term heterogeneous as applied to catalysts.

A heterogeneous catalyst is in different state / phase to the reactants. [1m]

[1]

(ii) Heterogeneous metal catalysts, such as rhodium and platinum are used in catalytic converters in cars. Write two equations to illustrate how NO and CO gases produced in car engines, are removed by catalytic converters.

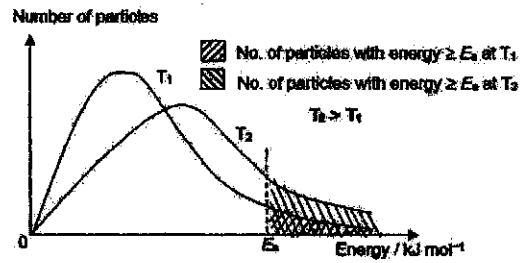
$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$ **[1m]**
$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$ **[1m]**

[2]

(b) The equation for this stage of the Contact Process is shown.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196$ kJmol^{-1}

(i) With the help of a suitable diagram, explain why a decrease in temperature decrease the rate of production of SO_3.



[1 for diagram]
When the temperature decreases(T_2 to T_1), the number of molecules with energy ≥ activation energy/ E_a decreases. [1m]
Therefore, frequency of effective collisions between molecules with energy ≥ activation energy/ E_a decreases [1m] and hence, the rate of reaction decreases. [3]

(ii) State and explain the effect of increasing pressure on the yield of SO_3.

By LCP, system will decrease the pressure by favouring the side of the equation that has lesser amount of gases. Equilibrium position shifts to the right. [2 points -1m] Yield of SO_3 increases. [1m] [2]

(c) Another element in the third period is silicon. Similarly to sulfur, silicon reacts with oxygen to form silicon dioxide which reacts with hot, concentrated sodium hydroxide.

(i) State the silicon containing product formed during the reaction between silicon dioxide and concentrated sodium hydroxide.

sodium silicate / Na_2SiO_3 **[1m]** [1]

(ii) Describe the behaviour of the silicon dioxide during this reaction.

Acid / acidic **[1m]** [1]

(d) Sodium burns in oxygen to form Na_2O.

(i) Which one of the two oppositely charged ions present in Na_2O would have a smaller ionic radius? Explain your answer.

Na^+ and O^{2-} are isoelectronic. Na^+ has a larger nuclear charge than O^{2-}. [1m]
Hence, Na^+ has a smaller radius than O^{2-}. [1m]

[2]

[Turn over

(ii) State and explain the difference in the melting points of Na_2O and MgO.

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

Mg^{2+} has higher ionic charge and smaller radius than Na^+.[1]
Larger amount of energy is required to overcome the stronger electrostatic attraction between Mg^{2+} and O^{2-} than that between Na^+ and O^{2-}. [1m]
MgO has a higher melting point than Na_2O. [1m]

[3]

(e) (i) Explain why Group 1 elements are generally good reducing agents.

Group 1 elements are easily oxidised as they have low first ionisation energies and easily lose an electron to form cations. [1m] Thus, they act as good reducing agents.

[1]

(ii) Explain why the reducing power of sodium is higher than that of lithium. Quote relevant values from the *Data Booklet* to support your answer.

The first ionisation energy of Li is greater than Na.
Li: 519 kJ mol^{-1}
Na: 494 kJ mol^{-1}
[1m]

Or atomic radius of Na is greater than Li.
Li: 0.152 nm
Na: 0.186 nm
[1m]

(The valence electrons are further away from the nucleus and hence more easily removed due to the weaker attraction to the nucleus)
It becomes easier to remove an electron from the atom from Na than Li, thus ease of oxidation increases. [1m]

Hence, reducing power of Na is higher than Li.

[2]

(f) When aqueous chlorine was added to a bromide solution, an orange solution, $Br_2(aq)$ was formed. However, when aqueous bromine was added to a chloride solution, no reaction occurred.

$$Cl_2(aq) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq) \ldots\ldots(1)$$

$$Br_2(aq) + 2Cl^-(aq) \rightarrow \text{no reaction} \ldots\ldots\ldots(2)$$

(i) State the role of $Cl_2(aq)$ in equation (1).

Oxidising agent.

[1]

(ii) Explain why there is no reaction in (2) while reaction proceeds in (1).

Cl_2, is a stronger oxidising agent than Br_2, so it oxidises Br^- to Br_2 and the reaction proceeds while in (2) Br_2 being a weaker oxidising agent, it was not able to oxidise Cl^- to Cl_2 [1]

[Total: 20]