JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME			
CLASS	**18S24**	EXAM INDEX	

CHEMISTRY 8873/01

Higher 1

Paper 1 Multiple Choice **13 September 2018**

1 hour

Candidates answer on separate paper.

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 **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** or **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.

[Turn over

1 When copper reacts with a 50% solution of nitric acid, nitrogen monoxide is evolved and a blue solution results.

The balanced equation for this reaction is shown.

$$p\text{Cu} + q\text{HNO}_3 \rightarrow r\text{Cu(NO}_3)_2 + s\text{H}_2\text{O} + t\text{NO}$$

What are the values of the integers *p, q, r, s* and *t*?

	p	*q*	*r*	*s*	*t*
A	1	4	1	2	2
B	2	6	2	3	2
C	2	8	2	4	4
D	3	8	3	4	2

2 A sample of silicon contains three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

The sample is made up of 92.23% ^{28}Si and the relative atomic mass of silicon in this sample is 28.10.

What is the percentage of the isotope ^{29}Si in the sample?

A 2.23% **B** 3.89% **C** 5.54% **D** 7.77%

3 The ^{68}Ge isotope is medically useful because it undergoes a natural radioactive process to give an isotope of a different element, ^{68}X, which can be used to detect tumours. This transformation of ^{68}Ge occurs when an electron enters the nucleus and changes a proton into a neutron.

Which statement about the composition of an atom of ^{68}X is correct?

A It has 4 electrons in its outer p orbitals.

B It has 13 electrons in its outer shell.

C It has 37 neutrons.

D Its proton number is 32.

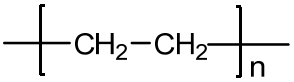
4 Drinking water may contain dissolved calcium hydrogencarbonate, $Ca(HCO_3)_2$.

How many electrons are present in a hydrogencarbonate anion?

A 30 **B** 31

C 32 **D** 33

5 In which structure are there three atoms bonded together in a straight line?

A Poly(ethene), 

B Propane, C_3H_8

C Silicon tetrachloride, $SiCl_4$

D Sulfur hexafluoride, SF_6

6 At room temperature and pressure, H_2O is a liquid and H_2S is a gas.

What is the reason for this difference?

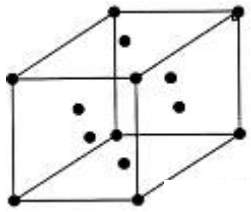
A O has higher first and second ionisation energies than S.

B The covalent bond between O and H is stronger than the covalent bond between S and H.

C There is significant hydrogen bonding between H_2O molecules but not between H_2S molecules.

D The instantaneous dipole-induced dipole forces between H_2O molecules are stronger than the instantaneous dipole-induced dipole forces between H_2S molecules.

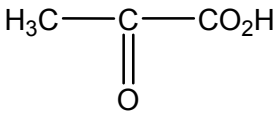
7 Copper and iodine are both shiny crystalline solids. The crystal structures of copper and iodine are both face-centred cubic. The diagram shows the arrangement of the particles in this type of crystal lattice.



What are the particles present in each lattice?

	Copper	iodine
A	atoms	anions
B	atoms	atoms
C	cations	atoms
D	cations	molecules

8 The diagram shows the structure of pyruvic acid.



pyruvic acid

Which set of bond angles in pyruvic acid would be predicted by Valence Shell Electron Pair Repulsion theory?

A 105°, 109°, 120°

B 105°, 120° only

C 109°, 120°, 180°

D 109°, 120° only

9 Which row describes and explains the trend in electronegativity from fluorine to iodine?

	trend in electronegativity	explanation
A	decreases	the bonding pair of electrons becomes further away from the nucleus and so is less attracted to it
B	decreases	ionisation energy decreases down the group because the outer electron is strongly attracted to the nucleus
C	increases	the bonding pair of electrons becomes further away from the nucleus and so is less attracted to it
D	increases	ionisation energy decreases down the group because the outer electron is strongly attracted to the nucleus

10 Which types of bond are broken and formed in the addition polymerisation of alkenes?

	Type of bond broken	Type of bond formed
A	π only	σ only
B	π only	σ and π
C	σ and π	σ only
D	σ and π	σ and π

11 All the reactants and products of an endothermic reaction are gaseous.

Which statements about this reaction is correct?

1 On the reaction pathway diagram, the energy of the products are lower than that of the reactants.

2 There is a net transfer of heat energy from the surroundings to the reacting system.

3 The total bond energy of the reactants is more than the total bond energy of the products.

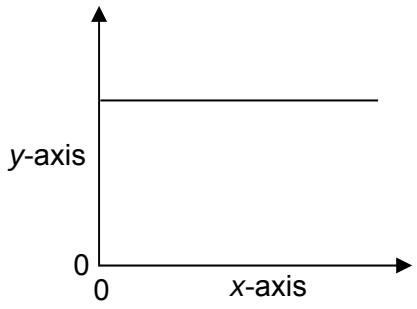
A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 3 only

12 The kinetics of the zero order reaction U $\rightarrow$ V were investigated under different conditions.
The table shows pairs of quantities that were plotted as graphs.
Which pairs gave the following graph?



	y-axis	*x*-axis
1	rate	time
2	rate constant	time
3	rate constant	temperature

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 and 3 only

13 Which statement about the effect of a catalyst on a reversible reaction is correct?

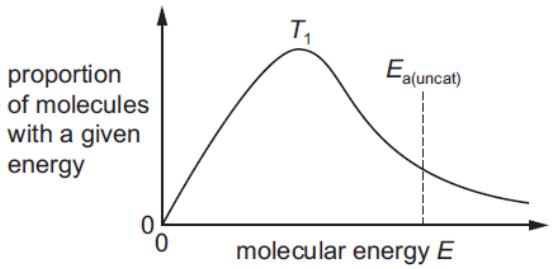
A The activation energy of the forward reaction stays the same.

B The composition of the equilibrium mixture stays the same.

C The rate of the backward reaction stays the same.

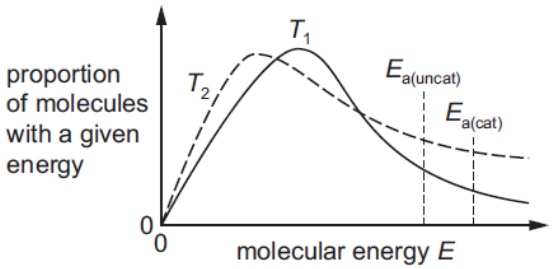
D The value of the equilibrium constant changes.

14 The diagram shows the distribution of molecular energies in a sample of gas at a temperature T_1. The activation energy for an uncatalysed reaction of this gas, $E_{a(uncat)}$, is shown.

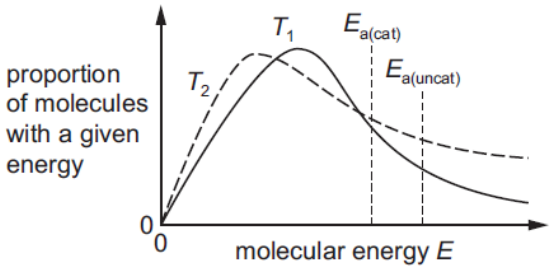


Which diagram correctly shows the new distribution and new activation energy, $E_{a(cat)}$, when the temperature is increased to T_2, and a catalyst is used that increases the rate of reaction?

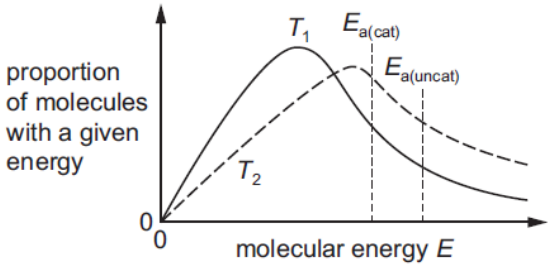
A



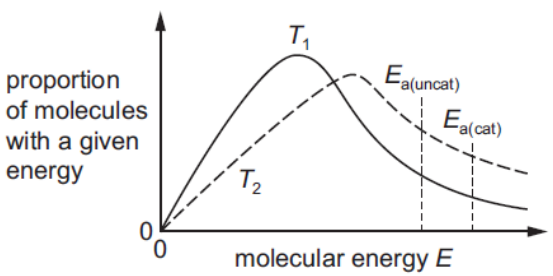
B



C



D



15 Nitrogen dioxide, NO_2, is a brown gas.
Dinitrogen tetroxide, N_2O_4, is a colourless gas.
An equilibrium is established between NO_2 and N_2O_4 in a closed vessel.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -57 \text{ kJ mol}^{-1}$$
brown colourless

Which row describes the effects of changing conditions on the colour of an equilibrium mixture of NO_2 and N_2O_4?

	Increasing the pressure	Increasing the temperature
A	Colour becomes darker	Colour becomes darker
B	Colour becomes darker	Colour becomes lighter
C	Colour becomes lighter	Colour becomes darker
D	Colour becomes lighter	Colour becomes lighter

16 The following equilibrium is an exothermic reaction in the forward direction.

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

What happens when the concentration of $CrO_4^{2-}(aq)$ ions **increases and** the temperature **decreases**?

1 The concentration of $Cr_2O_7^{2-}(aq)$ increases.
2 The equilibrium constant for the forward reaction increases.
3 The rate constants for the forward and reverse reactions increase equally.

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

17 The compound $(CH_3)_3NAlCl_3$ has a simple molecular structure.

Which statement about $(CH_3)_3NAlCl_3$ is correct?

A $(CH_3)_3NAlCl_3$ molecules attract each other by hydrogen bonds.
B The Al atom has an incomplete valence shell of electrons.
C The bonds around the Al atom are planar.
D The molecules contain coordinate and covalent bonding.

18 A solution was made by mixing 0.002 mol of H_2SO_4(aq) and 0.005 mol of KOH(aq). Water was added until the volume of the solution was 1 dm^3.

What is the pH of the solution?

A 11.0 **B** 11.5 **C** 11.7 **D** 12.0

19 Silver chloride and silver iodide form equilibria when added to water.

$$AgCl(s) \rightleftharpoons Ag^+(aq) + Cl^-(aq) \qquad K_c = K_1$$

$$AgI(s) \rightleftharpoons Ag^+(aq) + I^-(aq) \qquad K_c = K_2$$

Each equilibrium position lies well to the **left**.

Silver iodide will not dissolve in aqueous ammonia. Silver chloride will dissolve in aqueous ammonia. In both cases, adding aqueous ammonia will form the following equilibrium.

$$Ag^+(aq) + 2NH_3(aq) \rightleftharpoons Ag(NH_3)_2^+(aq) \qquad K_c = K_3$$

The position of this equilibrium lies to the **right**.

What is the order of magnitude for these three equilibrium constants?

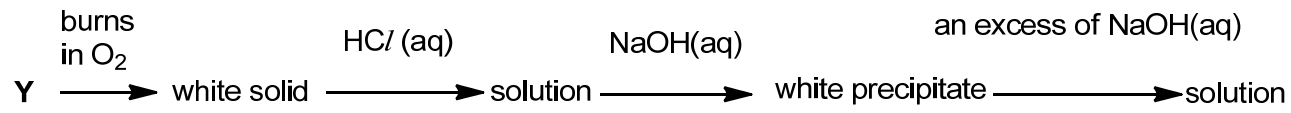
A $K_2 > K_3 > K_1$

B $K_2 > K_1 > K_3$

C $K_3 > K_1 > K_2$

D $K_3 > K_2 > K_1$

20 An element **Y** reacts according to the following sequence.



What could be element **Y**?

A Al **B** Ca **C** Mg **D** P

21 X_2, Y_2, Z_2 represent different halogens. The table shows the results of nine experiments in which aqueous solutions of X_2, Y_2 and Z_2 were separately added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

	$X^-(aq)$	$Y^-(aq)$	$Z^-(aq)$
$X_2(aq)$	No reaction	No reaction	No reaction
$Y_2(aq)$	X_2 formed	No reaction	Z_2 formed
$Z_2(aq)$	X_2 formed	No reaction	No reaction

Which row of the following table contains the ions X^-, Y^- and Z^- in order of their decreasing strength as reducing agents?

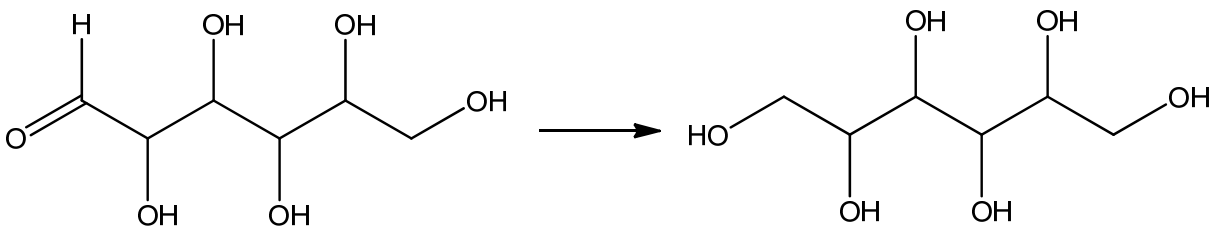
	strongest ⟶		weakest
A	X^-	Y^-	Z^-
B	X^-	Z^-	Y^-
C	Y^-	Z^-	X^-
D	Z^-	X^-	Y^-

22 1-bromopropane undergoes a variety of reactions.

Which row is correct?

	Reagent added to 1-bromopropane	Products include
A	Hot NaOH(aq)	Propene
B	Cold NaOH(aq)	Prop-2-ene
C	Hot NaOH in ethanol	Propene
D	Hot NaOH in ethanol	Propan-1-ol

23 Glucose can be used to prepare sorbitol, a compound used as a sugar substitute.



glucose sorbitol

Which reagent may be used for this conversion?

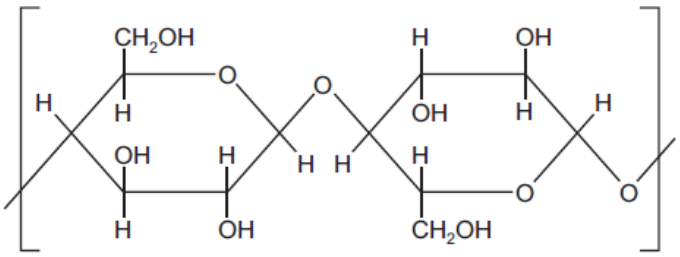
A Acidified potassium maganate(VII)

B Acidified potassium dichromate(VI)

C Sodium hydroxide

D Sodium borohydride

24 A cathedral in New Zealand has been constructed from cardboard. Cardboard contains polymer molecules. Part of one such polymer molecule is shown below.



Which statements about this polymer are correct?

1 The polymer molecules can form hydrogen bonds with each other.

2 The polymer can form intermolecular forces with water molecules.

3 The polymer will not burn easily because it is a secondary alcohol.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

25 Graphene, graphite and the fullerene C_{60} are allotropes of carbon.

Which statements are correct for all three of these allotropes of carbon?

1 Delocalised electrons are present in the structure.

2 All bond angles are 120°.

3 It has a giant molecular crystalline lattice structure.

A 1, 2 and 3

B 1 and 2 only

C 2 and 3 only

D 1 only

26 PVC, $-\left[-CH_2-CHCl-\right]_n-$ is difficult to dispose of.

Two possible methods are burying it in landfill sites and disposal by combustion.

Which row of the table is correct?

	Rate of biodegradation of PVC in landfill sites	Gases produced when PVC combusts
A	Fast	CO_2, H_2O, HCl
B	Fast	CO_2, H_2O, Cl_2
C	Slow	CO_2, H_2O, Cl_2
D	Slow	CO_2, H_2O, HCl

27 The gases butane, 2-methylpropane and propane are kept in a sealed container at atmospheric pressure and room temperature.

Which row represents the order in which these gases will liquefy as the pressure in the container is gradually increased?

	Increasing pressure →		
A	butane	2-methylpropane	propane
B	2-methylpropane	butane	propane
C	propane	butane	2-methylpropane
D	propane	2-methylpropane	butane

28 Silver foil does not react when added to a beaker of dilute hydrochloric acid. However, silver nanoparticles do react with dilute hydrochloric acid.

$$2Ag + 2HCl \rightarrow 2AgCl + H_2$$

Which statement could explain why silver nanoparticles are more reactive than silver foil?

A They act as catalysts for the reaction.

B They contain a much greater concentration of silver.

C They do not have an unreactive oxide layer.

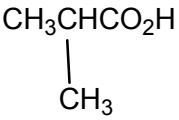
D They have a very high surface area to volume ratio.

29 Which molecular formula could represent molecules that exhibit *cis-trans* isomerism?

1	2	3	4
C_3H_6BrI	C_3H_5I	$C_3H_4I_2$	C_3H_4BrI

A 1, 2 and 3 **B** 2, 3 and 4 **C** 2 and 4 only **D** 3 and 4 only

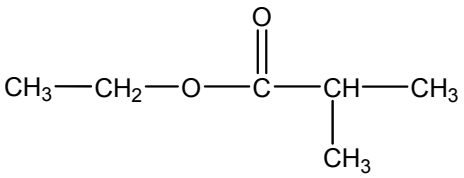
30 Ethyl propanoate is refluxed with aqueous sodium hydroxide. The alcohol produced is then reacted with methylpropanoic acid to make a second ester.



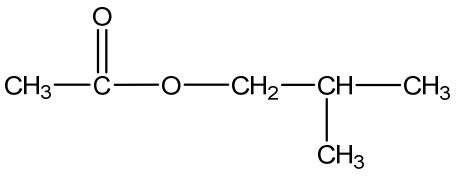
methylpropanoic acid

What is the structural formula of this second ester?

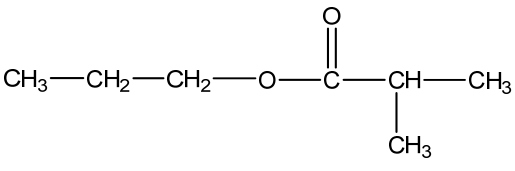
A



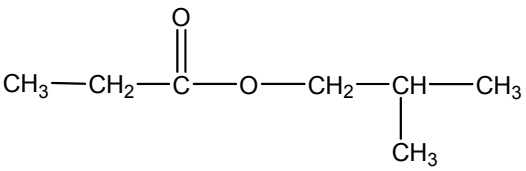
B



C



D



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JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION
Paper 1 answers

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

JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME			
CLASS	**18S24**	EXAM INDEX	

CHEMISTRY 8873/02

Higher 1

Paper 2 Structured Questions **29 August 2018**
2 hours

Candidates answer on the Question Paper.

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 an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in **Section A (60 marks)** in the space provided on the Question paper.
Answer **one** question in **Section B (20 marks)** in the space provided on the Question paper.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

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.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
Section B	
Lack **3sf** in final ans	**–1 / NA**
Missing/wrong **units** in final ans	**–1 / NA**
Total	

[Turn over

Section A

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

For Examiner's Use

1 An experiment was carried out to determine the percentage of iron in a sample of iron wire.

(a) A 3.35 g piece of wire was reacted with dilute sulfuric acid, in the absence of air, so that all of the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm^3.

(i) Write a balanced equation for the reaction between the iron in the wire and the sulfuric acid.

……..…… [1]

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0250 mol dm^{-3} potassium manganate(VII). 32.0 cm^3 of the potassium manganate(VII) solution was required for complete reaction.

The relevant half-equations for the reaction are shown below.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

(ii) Use these two half-equations to construct an ionic equation for the reaction between manganate(VII) ions and iron(II) ions in acid solution.

……..……

……..……

……..…… [2]

(iii) Calculate the amount, in moles, of manganate(VII) ions used in the titration.

[1]

(iv) Calculate the total amount, in moles, of iron(II) ions in 250 cm^3 of the solution.

[2]

For Examiner's Use

1 (a) (v) Hence, calculate the percentage by mass of iron in the 3.35 g piece of wire.

[2]

(b) The electronegativity values of some elements are shown in the table below.

element	electronegativity
aluminium	1.5
chlorine	3.0
iron	1.8

(i) Use the data to suggest the nature of the bonding in iron(III) chloride. Explain your answer.

……

……

……

…… [2]

(ii) When a piece of universal indicator paper is dipped into a solution of iron(III) chloride, the indicator paper turns red.

Suggest an equation to account for the colour change in the indicator paper.

……

…… [1]

[Total: 11]

For Examiner's Use

2 **(a)** State the difference between a nanoparticle and a nanomaterial in terms of size.

……

…… [1]

(b) Many modern sunscreens contain nano-sized particles of titanium dioxide. This substance does **not** absorb ultraviolet radiation.

Suggest how these nano-particles are able to protect skin from ultraviolet radiation.

……

…… [1]

(c) The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as nitrogen monoxide, NO. These substances are converted to less harmful gases on the catalyst surface before they are released into the atmosphere.

(i) One of the active materials present in the catalytic converter is platinum nanoparticles. Explain how the use of nanoparticles helps to increase the rate of gaseous reactions in the catalytic converter.

……

……

……

……

……

…… [2]

(ii) Give an equation for a reaction involved in the removal of nitrogen monoxide from the exhaust gases of the car, in the catalytic converter.

……

…… [1]

(iii) State one way in which nitrogen monoxide acts as air pollutant.

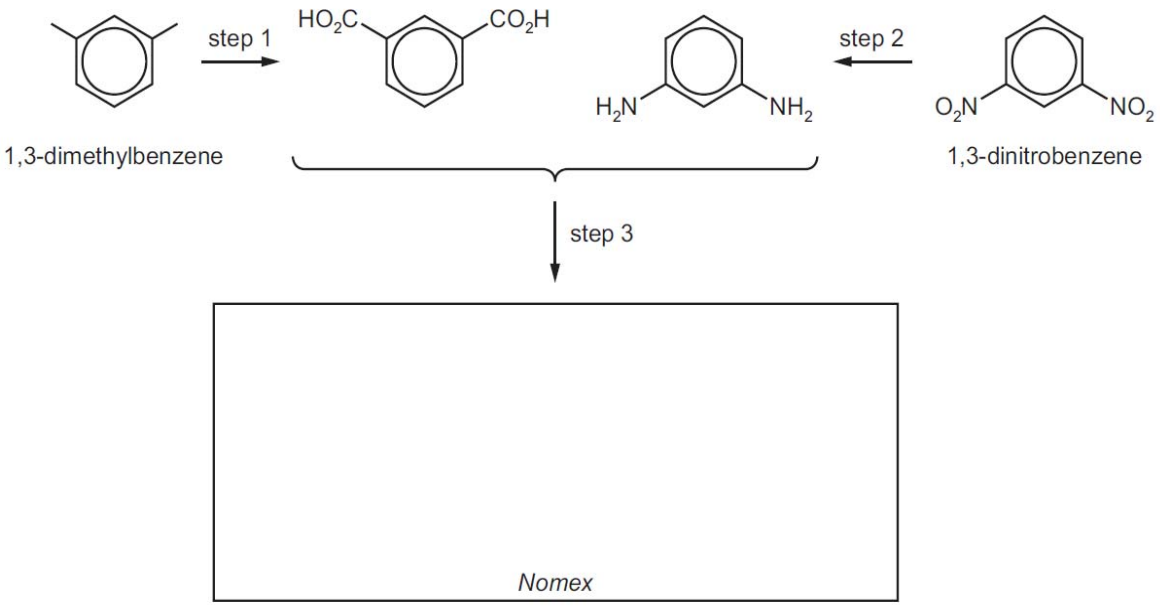
……

…… [1]

[Total: 6]

For Examiner's Use

3 1,3-dimethylbenzene is a starting material for the synthesis of the polymer *Nomex*, used in fireproof protective clothing worn by firefighters, military pilots and racing car drivers. The polymer is made from 1,3-dimethylbenzene and 1,3-dinitrobenzene by the following route.



(a) **(i)** Draw the structure of one repeat unit of *Nomex* in the box above. [1]

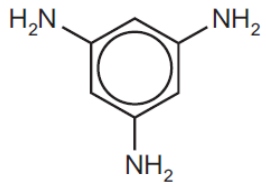
(ii) State the type of reaction that occurs in step 3.

……..…… [1]

(iii) Suggest the by-product formed in step 3.

[1]

(iv) Suggest how and why the properties of the polymer might change if some of the diamine monomer were replaced with 1,3,5-triaminobenzene.



1,3,5-triaminobenzene

……..……

……..…… [1]

For Examiner's Use

3 (b) Similar to *Nomex*, Nylon is also a polyamide.

(i) State one use, with reason, of nylon.

……

…… [1]

(ii) Nylon is non-biodegradable. What does this mean?

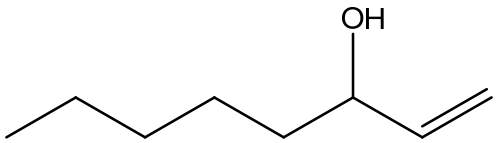
……

…… [1]

[Total: 6]

For Examiner's Use

4 1-octen-3-ol has the following structure.



This chemical is found in human sweat and breath, and is thought to attract biting insects such as mosquitoes. It is often used in combination with CO_2 in mosquito traps. It is also found in mushrooms, and sometimes called 'mushroom alcohol'.

(a) (i) State the type of reaction and what you would observe when 1-octen-3-ol reacts with a solution of bromine in tetrachloromethane (CCl_4).

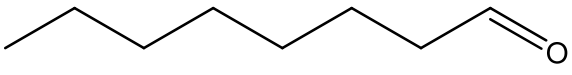
……

…… [2]

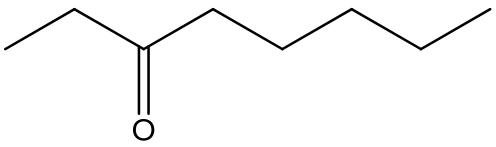
(ii) Draw the structure of the organic product formed when 1-octen-3-ol reacts with bromine in tetrachloromethane (CCl_4).

[1]

(b) Other examples of organic compounds containing eight carbon atoms are octanal and octan-3-one.



octanal



octan-3-one

(i) Octanal and octan-3-one can both be reduced using sodium borohydride, $NaBH_4$.

Draw the structural formula of the organic product obtained from the reduction of octanal and octan-3-one respectively.

Organic compound	Organic product obtained
Octanal	
Octan-3-one	

[2]

4 (b) (ii) Octanal and octan-3-one were heated separately with acidified potassium dichromate(VI). Write an equation for any reaction that occurs.

……

…… [1]

(c) Oct-3-ene, C_8H_{16}, has two isomers with the same structural formula.

Draw the **displayed** formulae of the two isomers and label them clearly.

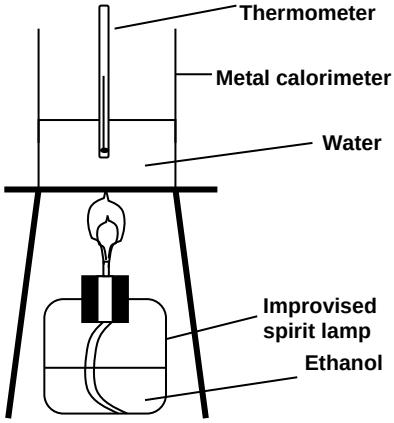
[2]

[Total: 8]

5 Biofuels such as ethanol, methanol and methane have been investigated as possible alternative fuels for motor vehicles that currently uses petrol.

(a) The enthalpy change of combustion of ethanol can be determined in the laboratory using the apparatus shown in the diagram below.

The heat produced by the burning fuel warms a known mass of water.



The following results were obtained.

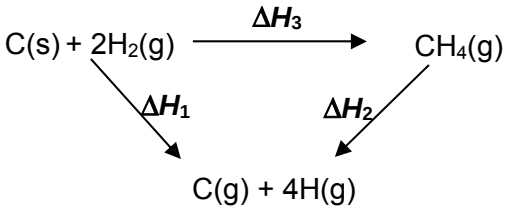
Mass of ethanol burnt (M_r = 46.0)	0.10 g
Initial temperature recorded	25.0 °C
Maximum temperature recorded	x °C
Enthalpy change of combustion of ethanol calculated	–840 kJmol^{-1}

Assume the total heat capacity of the calorimeter and its contents is 120 J K^{-1}, calculate the maximum temperature, x °C, recorded.

[3]

For Examiner's Use

5 (b) Consider the energy cycle below involving methane and the enthalpy changes, ΔH_1, ΔH_2 and ΔH_3.



(i) State *Hess's Law*.

……

……

…… [1]

(ii) Using the data given below, calculate ΔH_1.

$C(s) \rightarrow C(g)$ $\quad \Delta H = +715 \text{ kJ mol}^{-1}$

$H_2(g) \rightarrow 2H(g)$ $\quad \Delta H = +436 \text{ kJ mol}^{-1}$

[1]

(iii) What enthalpy change does ΔH_3 represent?

…… [1]

(iii) Using your answer to **(b)(ii)** and $\Delta H_3 = -75 \text{ kJ mol}^{-1}$, calculate ΔH_2.

[1]

(iv) Write an equation to represent the average C−H bond energy in methane, CH_4.

…… [1]

(v) Hence, calculate the average C−H bond energy in methane.

[1]

5 (c) Methane and sulfur react to produce carbon disulfide (CS_2), a liquid often used in the production of cellophane.

$$2CH_4(g) + S_8(s) \rightarrow 2CS_2(l) + 4H_2S(g)$$

(i) Write an equation to represent the standard enthalpy change of combustion of liquid carbon disulfide.

……..…… [1]

The tables below contain values of standard enthalpy change of combustion, $\Delta H^{\ominus}_c$, and standard enthalpy change of formation, $\Delta H^{\ominus}_f$, of some substances.

Table (I)

	C(graphite)	S(s)
$\Delta H^{\ominus}_c$ / kJ mol^{-1}	–394	–297

Table (II)

	$CS_2(l)$	CO(g)
$\Delta H^{\ominus}_f$ / kJ mol^{-1}	+88	–111

Use of relevant data given in **Tables (I)** and **(II)** is required to solve **c(ii)** and **c(iii)** of this question.

(ii) Calculate the standard enthalpy change of combustion of $CS_2(l)$.

[2]

(iii)) Carbon disulfide reacts explosively with nitrogen monoxide (NO) according to the following equation.

$$CS_2(l) + 5NO(g) \rightarrow CO(g) + 2SO_2(g) + \frac{5}{2}N_2(g)$$

Given the enthalpy change of this reaction is –1243 kJ mol^{-1}, calculate the enthalpy change of formation of NO(g) in this reaction.

[2]

[Total: 14]

For Examiner's Use

6 Ammonium nitrate is an important fertiliser made by the acid-base reaction between ammonia and nitric acid.

(a) (i) Write an equation for the production of ammonium nitrate from ammonia and nitric acid.

……..…… [1]

(ii) Describe the meaning of the terms *Bronsted acid* and *Bronsted* base. Identify the acid and base for the reaction in **(a)(i)**, in terms of the Bronsted-Lowry theory.

……..……

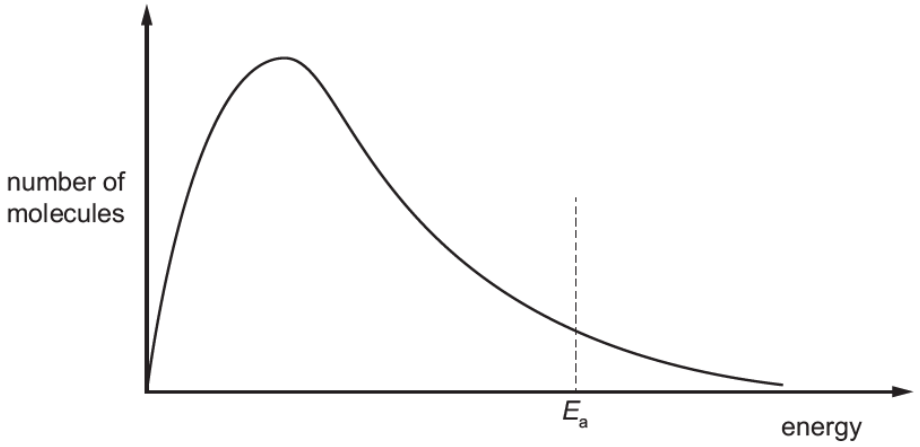
……..…… [2]

The ammonia for this reaction is produced by the Haber process and the nitric acid is produced by the oxidation of ammonia.

(b) The Haber process involves a reaction between nitrogen and hydrogen at a temperature of 450 ^{o}C and a pressure of 20 000 kPa.

$$N_2(g) + 3H_2(g) = 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The diagram below shows the Boltzmann distribution curve for the uncatalysed reaction between nitrogen and hydrogen at 450 ^{o}C. The *activation energy* of the reaction is labelled as E_a.



(i) The Haber process is an example of a large-scale gaseous reaction that is catalysed. State the catalyst used.

……..…… [1]

(ii) Explain the meaning of the term *activation energy*.

……..……

……..……

……..…… [1]

(iii) On the energy axis of the graph above, clearly mark the position of the activation energy of the catalysed reaction between nitrogen and hydrogen with the letter **C**. [1]

For Examiner's Use

6 (b) (iv) At a higher reaction temperature, the rate of production of ammonia would be greater. Explain why a higher temperature is **not** used despite the fact that it would increase the rate of production of ammonia.

……..……

……..……

……..…… [2]

(c) The first stage in the production of nitric acid involves the reaction of ammonia with oxygen to form nitrogen monoxide, NO, and water.

Write an equation for this reaction and use oxidation numbers to show that it is a redox reaction.

……..…….

……..…….

……..…….

……..……. [3]

(d) (i) Draw a dot-and-cross diagram of the ammonium ion. Show the outer electrons only.

[2]

(ii) State the shape of an ammonium ion and give the H–N–H bond angle.

shape……..…….

bond angle……..…… [2]

[Total: 15]

Section B

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

For Examiner's Use

7 **(a)** Sodium, silicon and chlorine are all elements in Period 3 of the Periodic Table.

Describe the variation in atomic radius, melting point, electrical conductivity and bonding of sodium, silicon and chlorine.

……

……

……

……

……

……

……

……

……

…… [5]

(b) Three of the oxides of Period 3 elements are sodium oxide, phosphorus(V) oxide and sulfur trioxide.

(i) Write equations for the reactions of each of these oxides with water.

[3]

(ii) Write an equation for the reaction of each oxide with either sodium hydroxide or hydrochloric acid.

[3]

For Examiner's Use

7 **(b)** **(iii)** Describe the variation in behaviour shown by these oxides across Period 3 as shown in **(b)(ii)**.

……

…… [1]

(c) **(i)** Write a balanced equation to represent the lattice energy of sodium chloride.

…… [1]

(ii) Explain why the lattice energy of magnesium oxide is much more exothermic than that of sodium chloride.

……

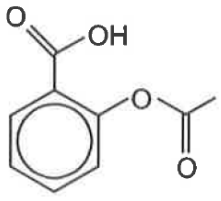
……

……

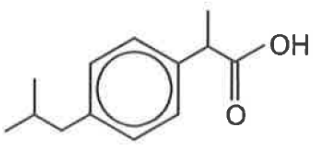
……

…… [2]

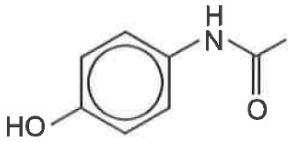
(d) The pharmaceuticals aspirin, ibuprofen and paracetamol are all painkillers.



aspirin



ibuprofen



paracetamol

Infra-red absorptions can be used to identify functional groups in organic compounds. For example, ethyl ethanoate shows absorptions at 1050–1330 cm^{-1} and 1710–1750 cm^{-1} as shown in the *Data Booklet*.

(i) Identify an infra-red absorption range that will be shown by aspirin and ibuprofen but **not** by paracetamol using the *Data Booklet*.

[1]

(ii) Identify two of the infra-red absorption range that will be shown by paracetamol but **not** by aspirin or ibuprofen using the *Data Booklet*.

[1]

7 **(d)** **(iii)** Identify a type of reaction which will occur with both paracetamol and aspirin but **not** with ibuprofen.

……..…… [1]

(iv) Write an equation for the reaction of ethanol with ethanoic acid. State the conditions required.

……..……

……..…… [2]

[Total: 20]

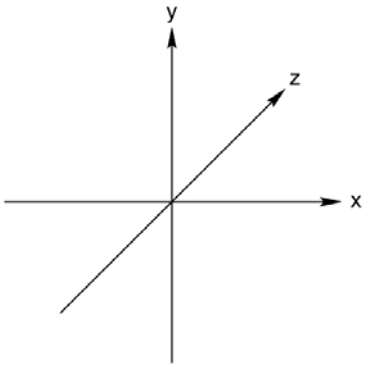
For Examiner's Use

8 This question is about phosphorus and its compounds.

(a) **(i)** State the full electronic configuration of phosphorus.

……..…… [1]

(ii) On the axes below, sketch the shape of the singly-occupied orbital in an atom of phosphorus at ground state.



[1]

(iii) The first ionisation energy of phosphorus is higher than that of sulfur. Explain why.

……..……

……..…… [1]

(b) The dissociation of phosphorus(V) chloride into phosphorus(III) chloride and chlorine gas is reversible:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

The reaction is an example of a *dynamic equilibrium*.

(i) Explain the meaning of the term *dynamic equilibrium*.

……..…… [1]

(ii) In an experiment, 1.00 mol of PCl_5 vapour was heated in a closed 5.00 dm^3 flask at 500 K until equilibrium had been established. When equilibrium is established, the percentage conversion of PCl_5 is found to be 51 %. Calculate the equilibrium constant, K_c, at this temperature and state its units.

[2]

8 (b) (iii) State and explain what would happen to the equilibrium position if the initial concentration of chlorine was increased.

……

…… [1]

(iv) Draw and name the shapes of PCl_3 and PCl_5.

[2]

(v) Explain why PCl_5 sublimes at 160°C while PCl_3 boils at a lower temperature of 76.1°C.

……

……

……

…… [1]

(d) Phosphorus compounds are used in the pharmaceutical industries. For example, solutions containing hydrogen phosphates are used as buffers found in the hydrophilic gel used in skin patches. Write equations to show how the solution containing $H_2PO_4^-$/ HPO_4^{2-} can act as a buffer when H^+ and OH^- ions are added respectively to the solution.

……

……

……

…… [2]

For Examiner's Use

8 (e) Phosphine, PH_3, is a widely used fumigant. The thermal decomposition of phosphine into phosphorus and hydrogen is a *first-order reaction.*

$$4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$$

(i) Explain the term in *italics*.

……

…… [1]

(ii) Sketch a graph of rate against concentration for the above decomposition reaction.

[1]

The half-life of the reaction is 35.0 seconds at 680 °C. Calculate

(iii) the rate constant for the reaction.

[1]

(iv) the time taken for 87.5% of the phosphine to decompose.

[1]

8 (f) Phosphorus compounds are also used in organic reactions, as shown in the following reactions. Suggest the type of reaction occurring in each case.

(i) Phosphoric(V) acid, H_3PO_4, is used as a catalyst in the reaction.

$$CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$$

……..…… [1]

(ii) Phosphorus(V) chloride reacts with ethanol.

$$CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2OH + POCl_3 + HCl$$

……..…… [1]

(g) Describe, in terms of orbital overlap, the bonding of the two carbon atoms of the C=C bond in $CH_2{=}CH_2$. A clearly labelled diagram may clarify your answer.

[2]

[Total: 20]

JURONG JUNIOR COLLEGE
2018 JC 2 PRELIMINARY EXAMINATION

CANDIDATE NAME			
CLASS	**18S24**	EXAM INDEX	

CHEMISTRY 8873/02

Higher 1

Paper 2 Structured Questions **29 August 2018**
2 hours

Candidates answer on the Question Paper.

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 an HB pencil for any diagrams, graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in **Section A (60 marks)** in the space provided on the Question paper.
Answer **one** question in **Section B (20 marks)** in the space provided on the Question paper.
The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

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.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
Section B	
Lack **3sf** in final ans	**–1 / NA**
Missing/wrong **units** in final ans	**–1 / NA**
Total	

[Turn over

Section A

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

For Examiner's Use

1 An experiment was carried out to determine the percentage of iron in a sample of iron wire.

(a) A 3.35 g piece of wire was reacted with dilute sulfuric acid, in the absence of air, so that all of the iron atoms were converted to iron(II) ions. The resulting solution was made up to 250 cm^3.

(i) Write a balanced equation for the reaction between the iron in the wire and the sulfuric acid.

$Fe(s) + H_2SO_4(aq) \rightarrow FeSO_4(aq) + H_2(g)$ ..... [1]

A 25.0 cm^3 sample of this solution was acidified and titrated with 0.0250 mol dm^{-3} potassium manganate(VII). 32.0 cm^3 of the potassium manganate(VII) solution was required for complete reaction.

The relevant half-equations for the reaction are shown below.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$$

$$Fe^{3+} + e^- \rightarrow Fe^{2+}$$

(ii) Use these two half-equations to construct an ionic equation for the reaction between manganate(VII) ions and iron(II) ions in acid solution.

$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$ .....

.....

..... [2]

(iii) Calculate the amount, in moles, of manganate(VII) ions used in the titration.

Amount of MnO_4^- used = $32.0/1000 \times 0.025$ = $\mathbf{8.00 \times 10^{-4}\ mol}$

[1]

(iv) Calculate the total amount, in moles, of iron(II) ions in 250 cm^3 of the solution.

Amount of Fe^{2+} in 25.0 cm^3 = $\mathbf{8.00 \times 10^{-4} \times 5}$ = 4.00×10^{-3} mol

Amount of Fe^{2+} in 250 cm^3 = $4.00 \times 10^{-3} \times 250/25.0$ = $\mathbf{4.00 \times 10^{-2}\ mol}$

[2]

For Examiner's Use

1 **(a)** **(v)** Hence, calculate the percentage by mass of iron in the 3.35 g piece of wire.

Mass of Fe in wire = **$4.00 \times 10^{-2} \times 55.8$** = 2.23 g

% by mass of Fe in wire = $2.23/3.35 \times 100$ % = **66.6 %**

[2]

(b) The electronegativity values of some elements are shown in the table below.

element	electronegativity
aluminium	1.5
chlorine	3.0
iron	1.8

(i) Use the data to suggest the nature of the bonding in iron(III) chloride. Explain your answer.

Covalent. Smaller difference in electronegativity between Fe and C*l* compared to between A*l* and C*l*.

[2]

(ii) When a piece of universal indicator paper is dipped into a solution of iron(III) chloride, the indicator paper turns red.

Suggest an equation to account for the colour change in the indicator paper.

$[Fe(H_2O)_6]^{3+}(aq) = [Fe(H_2O)_5OH]^{2+}(aq) + H^+(aq)$

[1]

[Total: 11]

For Examiner's Use

2 **(a)** State the difference between a nanoparticle and a nanomaterial in terms of size.

Nanoparticles ALL dimensions 1–100nm/on the **nanoscale**
AND **nanomaterial (at least) one dimension 1–100nm**/on the **nanoscale**
[1]

(b) Many modern sunscreens contain nano-sized particles of titanium dioxide. This substance does **not** absorb ultraviolet radiation.

Suggest how these nano-particles are able to protect skin from ultraviolet radiation.

The particles are **similar in size to the wavelength of uv light and deflect the harmful radiation**
[1]

(c) The engines of modern motor cars have exhaust systems which are fitted with catalytic converters in order to reduce atmospheric pollution from substances such as nitrogen monoxide, NO. These substances are converted to less harmful gases on the catalyst surface before they are released into the atmosphere.

(i) One of the active materials present in the catalytic converter is platinum nanoparticles. Explain how the use of nanoparticles helps to increase the rate of gaseous reactions in the catalytic converter.

Pt nanoparticles are used due to the high **surface area to volume ratio**
Due to the **large surface area, more platinum atoms are exposed to the reactants**. Hence, the catalyst provides an alternative reaction pathway of lower activation energy.
the **greater the frequency of effective collisions** between the reactants and catalyst, the higher the reaction rate.
[2]

(ii) Give an equation for a reaction involved in the removal of nitrogen monoxide from the exhaust gases of the car, in the catalytic converter.

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

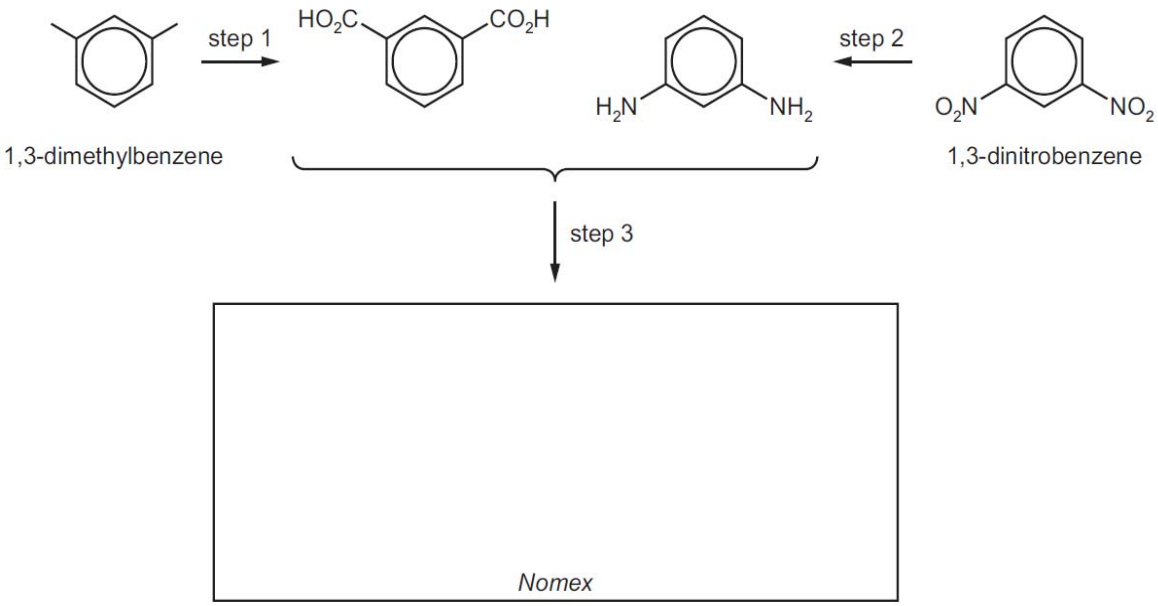
(iii) State one way in which nitrogen monoxide acts as air pollutant.

Formation of acid rain / causes smog
[1]

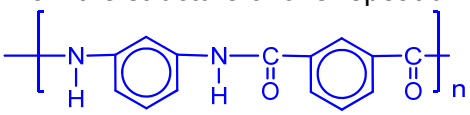
[Total: 6]

For Examiner's Use

3 1,3-dimethylbenzene is a starting material for the synthesis of the polymer *Nomex*, used in fireproof protective clothing worn by firefighters, military pilots and racing car drivers. The polymer is made from 1,3-dimethylbenzene and 1,3-dinitrobenzene by the following route.



(a) **(i)** Draw the structure of one repeat unit of *Nomex* in the box above.



[1]

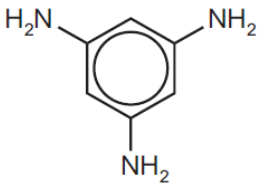
(ii) State the type of reaction that occurs in step 3.

condensation polymerisation [1]

(iii) Suggest the by-product formed in step 3.

H_2O / water [1]

(iv) Suggest how and why the properties of the polymer might change if some of the diamine monomer were replaced with 1,3,5-triaminobenzene.



1,3,5-triaminobenzene

Harder/more dense/stronger/higher melting point/tougher/more rigid due to cross-linking/more hydrogen bonding between the chains

[1]

For Examiner's Use

3 **(b)** Similar to *Nomex*, Nylon is also a polyamide.

(i) State one use, with reason, of nylon.

rope as it is strong / fabric as it is lightweight……

…… [1]

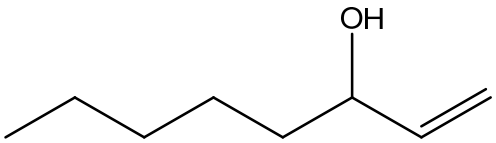
(ii) Nylon is non-biodegradable. What does this mean?

Cannot be broken down / changed to a harmless natural state by the action of bacteria / living organism

…… [1]

[Total: 6]

4 1-octen-3-ol has the following structure.



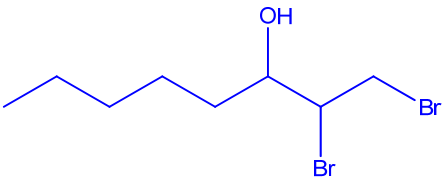
This chemical is found in human sweat and breath, and is thought to attract biting insects such as mosquito
mosquito traps. It is also found in mushrooms, and sometimes called 'mushroom alcoh

(a) (i) State the type of reaction and what you would observe when 1-octen-3-ol reacts with a solution o

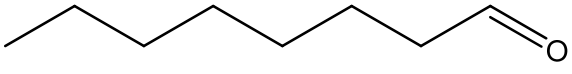
Electrophilic addition

Orange-red bromine decolourises.

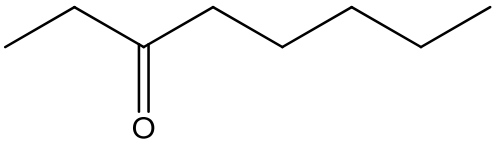
(ii) Draw the structure of the organic product formed when 1-octen-3-ol reacts with bromine in tetrach



(b) Other examples of organic compounds containing eight carbon atoms are octanal and octan-3-one.



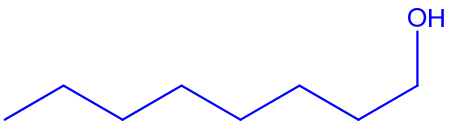
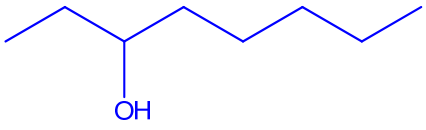
octanal



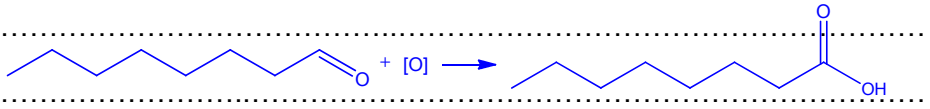
octan-3-one

(i) Octanal and octan-3-one can both be reduced using sodium borohydride, $NaBH_4$.

Draw the structural formula of the organic product obtained from the reduction of octanal and oct

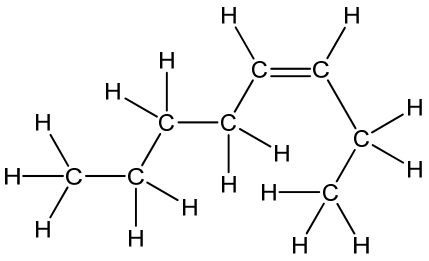
Organic compound	Organic product obtained
Octanal	
Octan-3-one	

4 (b) (ii) Octanal and octan-3-one were heated separately with acidified potassium dichromate(VI). Write

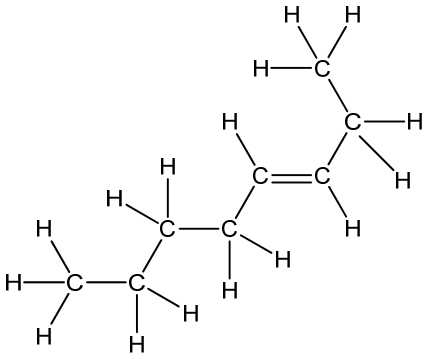


(c) Oct-3-ene, C_8H_{16}, has two isomers with the same structural formula.

Draw the **displayed** formulae of the two isomers and label them clearly.



cis-oct-3-ene

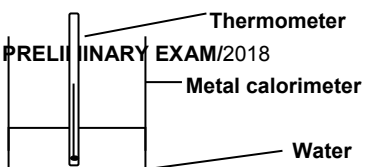


trans-oct-3-ene

5 Biofuels such as ethanol, methanol and methane have been investigated as possible alternative fuels for m

(a) The enthalpy change of combustion of ethanol can be determined in the laboratory using the apparatus

The heat produced by the burning fuel warms a known mass of water.



The following results were obtained.

Mass of ethanol burnt (M_r = 46.0)	0.10 g
Initial temperature recorded	25.0 °C
Maximum temperature recorded	x °C
Enthalpy change of combustion of ethanol calculated	–840 kJmol^{-1}

Assume the total heat capacity of the calorimeter and its contents is 120 J K^{-1}, calculate the maximum

Amount of ethanol burnt in the experiment

$= \frac{\mathbf{0.10}}{\mathbf{46.0}} = 0.00217$ mol

Heat evolved by combustion of 0.10 g of ethanol

= Heat used to raise temp. of water

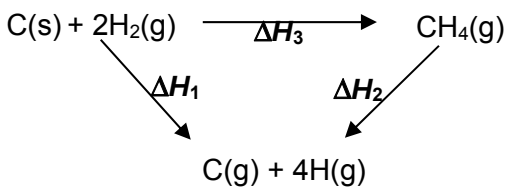
= **0.00217 × 840** = 1.82 kJ = **1820 J**

= **120 × ΔT**

ΔT = 15.2 K = 15.2 °C

Final max temp = 25.0 + 15.2 = **40.2 °C**

5 (b) Consider the energy cycle below involving methane and the enthalpy changes, ΔH_1, ΔH_2 and ΔH_3.



(i) State *Hess's Law*.

Hess' Law states that **the enthalpy change in a chemical reaction is constant and is independent of the reaction pathway between the initial and final states.**

……

……

……

(ii) Using the data given below, calculate ΔH_1.

$C(s) \rightarrow C(g)$ $\Delta H = +715$ kJ mol^{-1}

$H_2(g) \rightarrow 2H(g)$ $\Delta H = +436$ kJ mol^{-1}

$\Delta H_1 = +715 + 2(+436) =$ **+1587 kJ mol^{-1}**

(iii) What enthalpy change does ΔH_3 represent?

Standard enthalpy change of formation of methane ……

(iii) Using your answer to **(b)(ii)** and $\Delta H_3 = -75$ kJ mol^{-1}, calculate ΔH_2.

$\Delta H_2 = \Delta H_1 - \Delta H_3$

$=$ **+1587 – (–75)**

$=$ **+1662 kJ mol^{-1}**

(iv) Write an equation to represent the average C−H bond energy in methane, CH_4.

$\frac{1}{4}CH_4(g) \rightarrow \frac{1}{4}C(g) + H(g)$ ……

(v) Hence, calculate the average C−H bond energy in methane.

$\frac{1}{4} \times (+1662) =$ **+415.5 kJ mol^{-1}**

5 (c) Methane and sulfur react to produce carbon disulfide (CS_2), a liquid often used in the production of cell

$2CH_4(g) + S_8(s) \rightarrow 2CS_2(l) + 4H_2S(g)$

(i) Write an equation to represent the standard enthalpy change of combustion of liquid carbon disul

$CS_2(l) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$ ……

The tables below contain values of standard enthalpy change of combustion, $\Delta H_c^{\ominus}$, and standard enth substances.

Table (I)

	C(graphite)	S(s)
$\Delta H_c^\ominus$ / kJ mol^{-1}	–394	–297

Table (II)

	$CS_2(l)$	CO(g)
$\Delta H_f^\ominus$ / kJ mol^{-1}	+88	–111

Use of relevant data given in **Tables (I)** and **(II)** is required to solve **c(ii)** and **c(iii)** of this question.

(ii) Calculate the standard enthalpy change of combustion of $CS_2(l)$.

$\Delta H_r^\ominus$ = $\Sigma m\Delta H_c^\ominus$ (reactants) – $\Sigma n\Delta H_c^\ominus$ (products)

$\Delta H_f^\ominus(CS_2) = \Delta H_c^\ominus(C) + 2\Delta H_c^\ominus(S) - \Delta H_c^\ominus(CS_2)$

$+88 = -394 + 2(-297) - \Delta H_c^\ominus(CS_2)$

$\Delta H_c^\ominus(CS_2)$ = **– 1076 kJ mol^{-1}**

(iii) Carbon disulfide reacts explosively with nitrogen monoxide (NO) according to the following equat

$$CS_2(l) + 5NO(g) \rightarrow CO(g) + 2SO_2(g) + \frac{5}{2}N_2(g)$$

Given the enthalpy change of this reaction is –1243 kJ mol^{-1}, calculate the enthalpy change of fo

$\Delta H_r^\ominus$ = $\Sigma n\Delta H_f^\ominus$ (products) – $\Sigma m\Delta H_f^\ominus$ (reactants)

$-1243 = \Delta H_f^\ominus(CO) + 2\Delta H_f^\ominus(SO_2) + 5/2(0) - [\Delta H_f^\ominus(CS_2) + 5\Delta H_f^\ominus(NO)]$

$= -111 + 2(-297) - [(+88) + 5\Delta H_f^\ominus(NO)]$

$\Delta H_f^\ominus(NO)$ = **+90 kJ mol^{-1}**

6 Ammonium nitrate is an important fertiliser made by the acid-base reaction between ammonia and nitric aci

(a) (i) Write an equation for the production of ammonium nitrate from ammonia and nitric acid.

$NH_3(g) + HNO_3(l) \rightarrow NH_4NO_3(s)$

(ii) Describe the meaning of the terms *Bronsted acid* and *Bronsted* base. Identify the acid and b Bronsted-Lowry theory.

Bronsted acid is a proton donor and base is a proton acceptor

Acid – HNO_3, Base – NH_3

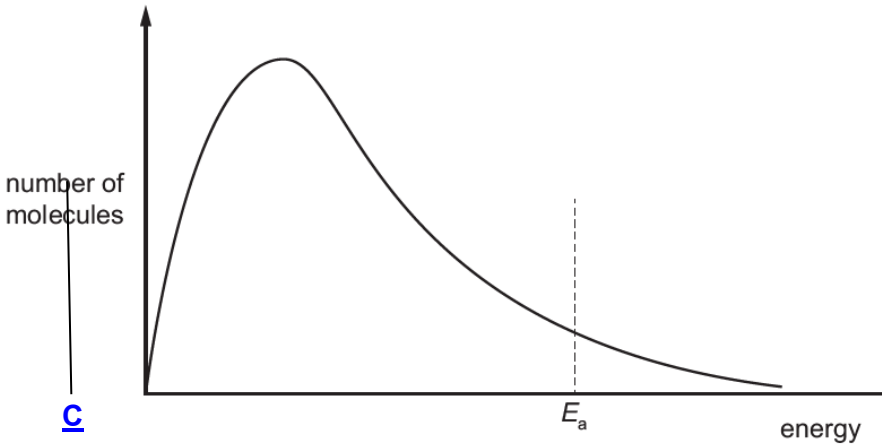
The ammonia for this reaction is produced by the Haber process and the nitric acid is produced by the oxida

(b) The Haber process involves a reaction between nitrogen and hydrogen at a temperature of 450 °C and

$$N_2(g) + 3H_2(g) = 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

The diagram below shows the Boltzmann distribution curve for the uncatalysed reaction between nitr

energy of the reaction is labelled as E_a.



(i) The Haber process is an example of a large-scale gaseous reaction that is catalysed. State the c

Iron / iron oxide

(ii) Explain the meaning of the term *activation energy*.

Activation energy (E_a) is **the minimum amount of energy that reactants must possess before a reaction can occur.**

(iii) On the energy axis of the graph above, clearly mark the position of the activation energy of hydrogen with the letter **C**.

6 (b) (iv) At a higher reaction temperature, the rate of production of ammonia would be greater. Explain the fact that it would increase the rate of production of ammonia.

Production of NH_3/forward reaction is exothermic

Position of equilibrium will shift left and yield would reduce at higher temperature.

(c) The first stage in the production of nitric acid involves the reaction of ammonia with oxygen to form nitr

Write an equation for this reaction and use oxidation numbers to show that it is a redox reaction.

$4NH_3(g) + 5O_2(g) \rightarrow 4NO + 6H_2O(l)$

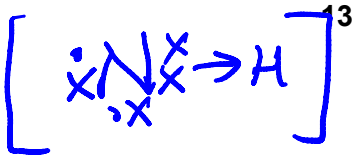
The **oxidation number of N increases from -3 in NH_3 to +2 in NO.**

Hence, **oxidation** has taken place.

The **oxidation number of O decreases from 0 in O_2 to -2 in H_2O.**

Hence, **reduction** has taken place.

(d) (i) Draw a dot-and-cross diagram of the ammonium ion. Show the outer electrons only.



13

(ii) State the shape of an ammonium ion and give the H–N–H bond angle.

shape……**tetrahedral**……

bond angle……**109/109.5°**……

Section B

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

For Examiner's Use

7 **(a)** Sodium, silicon and chlorine are all elements in Period 3 of the Periodic Table.

Describe the variation in atomic radius, melting point, electrical conductivity and bonding of sodium, silicon and chlorine.

Atomic radius:

Atomic radius decreases from Na to Si to C*l* due to increase in nuclear charge while the shielding effect by inner shell electrons remains almost constant across the period**.**

Melting point:

Na has a relatively **high melting point, Si** has the **highest melting point, Cl_2** has the **lowest melting point**

Electrical conductivity:

Na is a good electrical conductor due to presence of mobile electrons in its metallic structure.

Si is a semi-conductor and **C*l* is a non-electrical conductor** due to absence of mobile charge carriers in its structure

Bonding:

Na has **strong electrostatic forces of attraction between the delocalised electrons and Na^+ ions.**

Si has strong covalent bonds between Si atoms.

Cl_2 molecules consists of C*l* atoms are **bonded by strong covalent bonds, weak induced dipole-induced dipole interaction/attraction exist between Cl_2 molecules**.

[5]

(b) Three of the oxides of Period 3 elements are sodium oxide, phosphorus(V) oxide and sulfur trioxide.

(i) Write equations for the reactions of each of these oxides with water.

$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$ or $P_2O_5(s) + 3H_2O(l) \rightarrow 2H_3PO_4(aq)$

$SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$

[3]

(ii) Write an equation for the reaction of each oxide with either sodium hydroxide or hydrochloric acid.

$Na_2O(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + H_2O(l)$

$P_4O_{10}(s) + 12OH^-(aq) \rightarrow 4PO_4^{3-}(aq) + 6H_2O(l)$ Accept HPO_4^{2-} and $H_2PO_4^-$

$SO_3(l) + 2OH^-(aq) \rightarrow SO_4^{2-}(aq) + H_2O(l)$

[3]

7 **(b)** **(iii)** Describe the variation in behaviour shown by these oxides across Period 3 as shown in **(b)(ii)**.

For Examiner's Use

From basic in Na_2O to acidic in SO_3 and P_4O_{10}

[1]

(c) **(i)** Write a balanced equation to represent the lattice energy of sodium chloride.

$Na^+(g) + Cl^-(g) \rightarrow NaCl(s)$ [1]

(ii) Explain why the lattice energy of magnesium oxide is much more exothermic than that of sodium chloride.

Ions in MgO are Mg^{2+} and O^{2-}

Ions in NaCl are Na^+ and Cl^-.

$|L.E.| \propto \frac{q_+ q_-}{r_+ + r_-}$

charge of Na^+ is smaller than that of Mg^{2+}

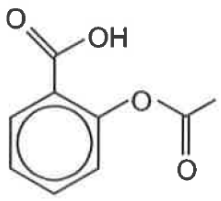
charge of Cl^- is smaller than that of O^{2-}

radius of Na^+ is greater than that of Mg^{2+}.

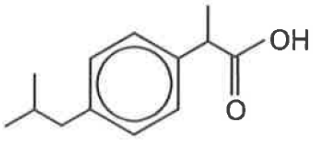
radius of Cl^- is greater than that of O^{2-}.

Therefore, the lattice energy of MgO is expected to be more exothermic. [2]

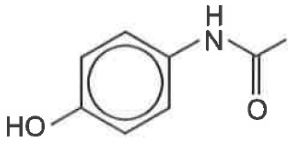
(d) The pharmaceuticals aspirin, ibuprofen and paracetamol are all painkillers.



aspirin



ibuprofen



paracetamol

Infra-red absorptions can be used to identify functional groups in organic compounds. For example, ethyl ethanoate shows absorptions at 1050–1330 cm^{-1} and 1710–1750 cm^{-1} as shown in the *Data Booklet*.

(i) Identify an infra-red absorption range that will be shown by aspirin and ibuprofen but **not** by paracetamol using the *Data Booklet*.

1680 – 1730 / 2500 – 3000 / 1210 – 1440 (cm^{-1})

[1]

(ii) Identify two of the infra-red absorption range that will be shown by paracetamol but **not** by aspirin or ibuprofen using the *Data Booklet*.

Any 2 from:

3300 – 3500 / 1640 – 1690 / 3200 – 3600 / 3580 – 3650 (cm^{-1})

[1]

7 **(d)** **(iii)** Identify a type of reaction which will occur with both paracetamol and aspirin but **not** with ibuprofen.

Hydrolysis

[1]

(iv) Write an equation for the reaction of ethanol with ethanoic acid. State the conditions required.

$CH_3CO_2H + CH_3CH_2OH \rightleftharpoons CH_3CO_2CH_2CH_3 + H_2O$

Conditions: conc H_2SO_4, heat under reflux

[2]

[Total: 20]

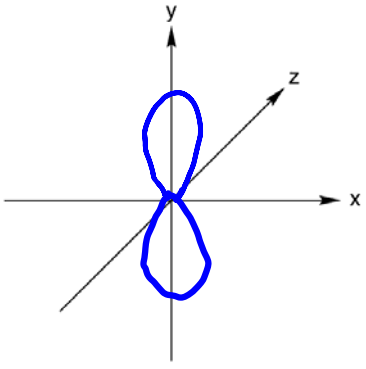
For Examiner's Use

8 This question is about phosphorus and its compounds.

(a) **(i)** State the full electronic configuration of phosphorus.

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ [1]

(ii) On the axes below, sketch the shape of the singly-occupied orbital in an atom of phosphorus at ground state.



[1]

(iii) The first ionisation energy of phosphorus is higher than that of sulfur. Explain why.

Mutual repulsion between the paired 3p electrons in sulfur makes it easier to remove the one of the paired **3p electrons from sulfur** than to remove the unpaired 3p electron from phosphorus which does not experience such repulsion. [1]

(b) The dissociation of phosphorus(V) chloride into phosphorus(III) chloride and chlorine gas is reversible:

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

The reaction is an example of a *dynamic equilibrium*.

(i) Explain the meaning of the term *dynamic equilibrium*.

Rate of forward reaction equals to rate of backward reaction ..... [1]

(ii) In an experiment, 1.00 mol of PCl_5 vapour was heated in a closed 5.00 dm^3 flask at 500 K until equilibrium had been established. When equilibrium is established, the percentage conversion of PCl_5 is found to be 51 %. Calculate the equilibrium constant, K_c, at this temperature and state its units.

	$PCl_5(g)$	$\rightleftharpoons$	$PCl_3(g)$	+	$Cl_2(g)$
initial amount/mol	1.00		0		0
		– 1.00(0.51)	+ 0.51		+ 0.51
eqm amount/mol	**0.49**		**0.51**		**0.51**

$$K_c = \frac{[PCl_3][Cl_2]}{[PCl_5]} = \frac{(\frac{0.51}{5})(\frac{0.51}{5})}{(\frac{0.49}{5})} = \textbf{0.106 mol dm}^{-3}$$

[2]

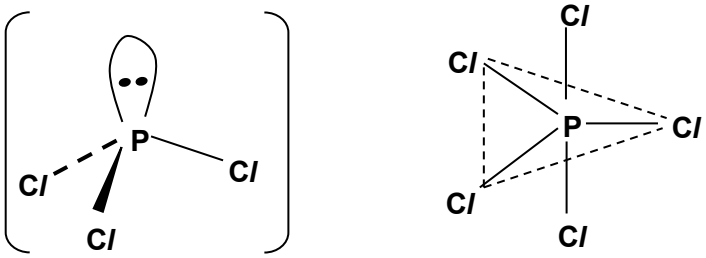
8 **(b)** **(iii)** State and explain what would happen to the equilibrium position if the initial concentration of chlorine was increased.

For Examiner's Use

Equilibrium position **shift to the right to remove some of the Cl_2** .....

..... [1]

(iv) Draw and name the shapes of PCl_3 and PCl_5.



trigonal pyramidal **trigonal bipyramidal**

[2]

(v) Explain why PCl_5 sublimes at 160°C while PCl_3 boils at a lower temperature of 76.1°C.

Both PCl_5 and PCl_3 have simple molecular structures.
.....
Due to the **larger number of electrons in** the **PCl_5** molecule**/ larger electron cloud of PCl_5** molecule ..... [1]

more energy/ larger amount of energy is required to overcome/break the **stronger induced dipole-induced dipole interaction/attraction between PCl_5 molecules** than the **weaker permanent dipole-permanent dipole interaction/attraction between PCl_3 molecules**

……

……

(d) Phosphorus compounds are used in the pharmaceutical industries. For example, solutions containing hydrogen phosphates are used as buffers found in the hydrophilic gel used in skin patches. Write equations to show how the solution containing $H_2PO_4^-$/ HPO_4^{2-} can act as a buffer when H^+ and OH^- ions are added respectively to the solution.

On addition of H^+: **$HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$**

On addition of OH^-: **$H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$**

……

…… [2]

For Examiner's Use

8 **(e)** Phosphine, PH_3, is a widely used fumigant. The thermal decomposition of phosphine into phosphorus and hydrogen is a *first-order reaction.*

$$4PH_3(g) \rightarrow P_4(g) + 6H_2(g)$$

(i) Explain the term in *italics*.

A first-order reaction refers to one in which **the order of reaction with respect to the reactant is one in the rate equation**.

OR

In a first-order reaction, the **power** to which a **concentration of reactant** is raised in the **rate equation is one**.

OR

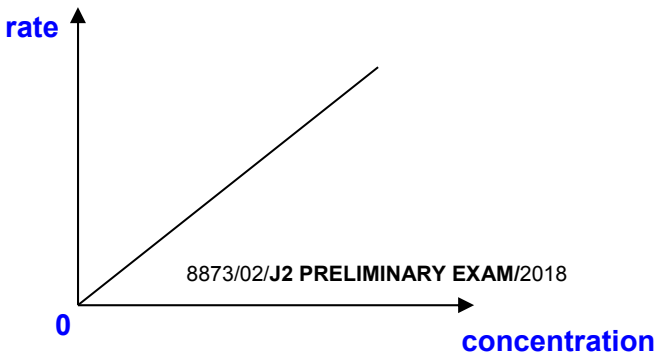
Consider an **experimentally determined rate equation**,

Rate = $k[A]^1$,

for a first-order reaction, **order of reaction with respect to A = 1**.

[1]

(ii) Sketch a graph of rate against concentration for the decomposition reaction.



[1]

The half-life of the reaction is 35.0 seconds at 680 °C. Calculate

(iii) the rate constant for the reaction.

$k = \ln 2/t_{1/2} = \ln 2/35.0 =$ **$0.0198\ s^{-1}$** [1]

(iv) the time taken for 87.5% of the phosphine to decompose.

100% → 50% → 25% → 12.5%

Time taken = 4 × 35.0 = **140 s** [1]

(f) Phosphorus compounds are also used in organic reactions, as shown in the following reactions. Suggest the type of reaction occurring in each case.

(i) Phosphoric(V) acid, H_3PO_4, is used as a catalyst in the reaction.

$$CH_2{=}CH_2 + H_2O \rightarrow CH_3CH_2OH$$

addition

(ii) Phosphorus(V) chloride reacts with ethanol.

$$CH_3CH_2OH + PCl_5 \rightarrow CH_3CH_2OH + POCl_3 + HCl$$

substitution [1]

(g) Describe, in terms of orbital overlap, the bonding of the two carbon atoms of the C=C bond in $CH_2{=}CH_2$. A clearly labelled diagram may clarify your answer.

In ethene, one sp^2 orbital of C atom overlaps head-on with the sp^2 orbital of another C atom, forming a C–C sigma bond.

The *unhybridised* 2p orbital of C atom overlaps side-way with the *unhybridised* 2p orbital of another C atom, forming a C–C π bond.

Or accept clearly labelled diagram [2]

[Total: 20]

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