# Advanced Higher Chemistry Past Papers 

October 2020

## 1 About this study aid...

This document has been designed to make revision and self-marking easy for students studying AH chemistry in Scotland.

The information in this publication has been reproduced to support SQA qualifications only on a noncommercial basis and can only be shared on that condition.

## 2 How to use...

The following two pages contain tables which cross-reference the course topics with SQA question numbers for the years 2014-19.

The first table is for multiple choice questions; the second accesses Section 2 questions. Each question number is hyperlinked to the SQA question and clicking it will take you there. The question pages have further hyperlinks taking you back to the topic grid (top) or to the SQA marking instructions (bottom).
Of course, you can always just treat it as a succession of question papers with marking instructions. This will be useful for end-of-course timed revision.

The SQA papers are embedded in this document to avoid the problems of broken hyperlinks to web pages that have disappeared. The document is self contained and does not require an internet connection and so is useable anywhere. Mr Sinclair, Vale of Leven Academy

| Section 1 Qs |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Unit | Topic | $\begin{aligned} & \text { RAH } \\ & 2014 \end{aligned}$ | $\begin{aligned} & \text { RAH } \\ & 2015 \end{aligned}$ | $\begin{gathered} \text { AH } \\ 2016 \end{gathered}$ | $\begin{gathered} \text { AH } \\ 2017 \end{gathered}$ | $\begin{gathered} \text { AH } \\ 2018 \end{gathered}$ | $\begin{gathered} \text { AH } \\ 2019 \end{gathered}$ |
|  | EM Radiation and Spectra | 467 | 12 | 1 |  | 1 | 1 |
|  | Atomic orbitals and electron config | $\begin{gathered} 1235 \\ 10 \end{gathered}$ | 34 | 23 | 1234 | 235 | 4 |
|  | Shape \& Polyatomic molecules | 89 | 5 | 4 |  | 4 | 5 |
|  | Transition metals | 11 | 6789 | 5 | 5 | 56 | 678 |
|  | Chemical Equilibrium |  | 202124 | 678 | 67 | $\begin{gathered} 78910 \\ 1112 \end{gathered}$ | 929 |
|  | Reaction Feasibility |  | 222324 | 910 | 8 | 13 | 101112 |
|  | Kinetics | 1314 | 25 | 11 | 910 | 14 | 1314 |
|  | Molecular Orbitals | 15 | 101118 | 1213 | 1112 | 15 | 1516 |
|  | Synthesis | $\begin{gathered} 181920 \\ 212223 \\ 2425 \end{gathered}$ | $\begin{gathered} 151617 \\ 26 \end{gathered}$ | $\begin{gathered} 141516 \\ 171819 \\ 202122 \\ 23 \end{gathered}$ | $\begin{gathered} 141516 \\ 1718 \end{gathered}$ | 1819 | $\begin{gathered} 192021 \\ 22 \end{gathered}$ |
|  | Stereochemistry | 1617 | 1314 |  | 13 | 17 | 1718 |
|  | Exp Determination of Structure | $\begin{gathered} 262728 \\ 29 \end{gathered}$ | 19 | 25 | 1920 | 23 | 232425 |
|  | Drug Interactions | 30 |  |  | 21 |  | 26 |
|  | Stoichiometric Calculations |  | 2730 | $\begin{gathered} 262728 \\ 2930 \end{gathered}$ | 272829 | 1624 | 27 |
|  | Gravimetric analysis |  | 30 | 29 | 22 | 28 | 23 |
|  | Volumetric analysis |  |  |  | 2527 |  |  |
|  | Practical skills |  | 2829 |  | $\begin{gathered} 232425 \\ 30 \end{gathered}$ | $\begin{gathered} 252627 \\ 2930 \end{gathered}$ | 282930 |


| Section 2 Qs |  |  |  |  |  |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Unit | Topic | $\begin{aligned} & \text { RAH } \\ & 2014 \end{aligned}$ | $\begin{aligned} & \text { RAH } \\ & 2015 \end{aligned}$ | $\begin{gathered} \text { AH } \\ 2016 \end{gathered}$ | $\begin{gathered} \text { AH } \\ 2017 \end{gathered}$ | $\begin{gathered} \text { AH } \\ 2018 \end{gathered}$ | $\begin{gathered} \text { AH } \\ 2019 \end{gathered}$ |
|  | EM Radiation and Spectra | 1a 1d | 1b | 6 a | 1 | 1 a | 4a 4c 7d |
|  | Atomic orbitals and electron config | 1b 1c | 1a 4c | 23 | 4aii | 1b 10b | 1a 4 |
|  | Shape \& Polyatomic molecules |  |  |  | 2b |  |  |
|  | Transition metals |  | 5 | 3 | $\begin{gathered} \text { 4ai 4bii } \\ \text { 6a } \end{gathered}$ | 4a 6a 6b | 4b |
| $\begin{aligned} & \overline{\overparen{Y}} \\ & \stackrel{N}{n} \\ & \stackrel{i}{\sim} \end{aligned}$ | Chemical Equilibrium | 513 | 6 a | 59 bii | $\begin{gathered} \text { 2a 6bi } \\ 6 \text { bii } \end{gathered}$ | 2 | $\begin{gathered} 1 c 4 a 4 b \\ 4 c \end{gathered}$ |
|  | Reaction Feasibility | 3 | 2 | 1 | 3 | 4d | 1b |
|  | Kinetics | 11a 11b | 6b | 6b | 4bi 4bii | 9d | 2 |
| $\begin{aligned} & . \frac{U}{E} \\ & \sqrt{50} \\ & 0.0 \end{aligned}$ | Molecular Orbitals |  | 9a 9b | 9a |  | 5 | 7b 7c |
|  | Synthesis | $\begin{gathered} 689 \\ 11 \mathrm{c} 11 \mathrm{~d} \end{gathered}$ | $\begin{gathered} \text { 4a } 8 \text { 9d } \\ 10 \text { 11a } \end{gathered}$ | 7c 8b 8c <br> 8d 8e | 9 11c | $\begin{gathered} \text { 7a 9a 9b } \\ 10 a \end{gathered}$ | $\begin{gathered} 9 b 10 a \\ 10 \mathrm{~b} 10 \mathrm{c} \end{gathered}$ |
|  | Stereochemistry | 9a 11d | 9c 10 | $7 \mathrm{7a}$ 7 | 8b 8c | 4b 4c | 9a 10d |
|  | Exp Determination of Structure | 9b 8a | $\begin{aligned} & 4 \mathrm{e} 10 \mathrm{e} \\ & 11 \mathrm{a} 12 \end{aligned}$ | 10 | 8a 11b | 9c 10d | 7d 10e |
|  | Drug Interactions | 7 a |  | 8 a | 8d |  |  |
|  | Stoichiometric Calculations | $\begin{gathered} 1 \mathrm{e} 27 \mathrm{~b} \\ 912 \end{gathered}$ | 3 4c | 4 9bv | 4bii 6biii <br> 7a 10a | $\begin{gathered} 36 c 7 b \\ 8 a \end{gathered}$ | $\begin{gathered} 3 \text { 4c } 6 \\ 9 b \end{gathered}$ |
|  | Gravimetric analysis | 212 |  | 4 | 6biii | 3a 3b 6c |  |
|  | Volumetric analysis | 2 | 3 | 4 | 10a |  |  |
|  | Practical skills | 5b 8a | 4b 4d 9e | $\begin{gathered} 49 \mathrm{bi} \\ 9 \mathrm{bii} 9 \mathrm{biv} \end{gathered}$ | 7a 11a | $\begin{gathered} 7 c 8 b 8 c \\ 10 c \end{gathered}$ | 3 7a 7d |
|  |  |  |  |  |  |  |  |
|  | Open-ended Qs | 410 | 7 11b | 3biii 8f | 510 b | 3 c 8 d | 4d 8 |

## X273/13/02

NATIONAL<br>QUALIFICATIONS 2014

## CHEMISTRY <br> ADVANCED HIGHER (REVISED)

Reference may be made to the Chemistry Higher and Advanced Higher Data Booklet.

## SECTION A - 30 marks

Instructions for completion of SECTION A are given on page two.
For this section of the examination you must use an HB pencil.

## SECTION B - 70 marks

All questions should be attempted.
Answers must be written clearly and legibly in ink.

1. The quantum number which specifies the shape of an orbital is the

A principal quantum number
B angular momentum quantum number
C magnetic quantum number
D spin quantum number.
2. Element number 104 in the Periodic Table is

A an s-block element
B a p-block element
C a d-block element
D an f-block element.
3. Which of the following statements is incorrect about electronic configurations of all first row transition metal atoms in their ground states?

A The five 3d orbitals are degenerate.
B They all have at least one electron in the 4 s orbital.

C Electrons begin to fill the 3d orbitals only after the 4 s orbital is full.
D When transition metal atoms form ions, the 4 s electrons are lost first.
4. The colour of a highly concentrated ionic solution which absorbs light only in the ultraviolet region of the electromagnetic spectrum is

A red
B black
C violet
D colourless.
5. The Pauli Exclusion Principle states that

A electrons fill degenerate orbitals singly
B electrons fill orbitals in order of increasing energy
C when degenerate orbitals are half filled all their electrons have parallel spins

D no two electrons in the one atom can have the same set of four quantum numbers.
6. The energy associated with a photon of electromagnetic radiation is

A independent of the frequency
B proportional to the frequency
C inversely proportional to the frequency
D proportional to the square of the frequency.
7. In absorption spectroscopy, as the concentration of an ion in solution increases, there is an increase in the

A wavelength of radiation absorbed
B frequency of radiation absorbed
C intensity of radiation absorbed
D intensity of radiation transmitted.
8. Which of the following has bond angles equal to $90^{\circ}$ ?

A $\quad \mathrm{SF}_{6}$
B $\mathrm{NH}_{4}^{+}$
C $\quad \mathrm{SiCl}_{4}$
D $\mathrm{BeF}_{4}{ }^{2-}$
9. Which of the following does not have a pyramidal structure?

A $\quad \mathrm{BF}_{3}$
B $\mathrm{NH}_{3}$
C $\mathrm{OH}_{3}{ }^{+}$
D $\mathrm{PH}_{3}$
10. The electronic configuration of a vanadium atom in its ground state is

A $\quad 1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{6} 3 d^{5}$
B $\quad 1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{6} 4 s^{2} 4 p^{3}$
C $\quad 1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{6} 3 d^{3} 4 s^{2}$
D $\quad 1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{6} 3 d^{4} 4 s^{1}$.
11. The highest oxidation state of chlorine is present in

A HClO
B $\mathrm{HClO}_{2}$
C $\mathrm{HClO}_{3}$
D $\mathrm{HClO}_{4}$.
12.


Iodine was added to $50 \mathrm{~cm}^{3}$ of two immiscible solvents X and Y as shown. After shaking, the following equilibrium was established.
$\mathrm{I}_{2}(\mathrm{Y}) \rightleftharpoons \mathrm{I}_{2}(\mathrm{X})$
An extra $10 \mathrm{~cm}^{3}$ of solvent X was added, the mixture shaken and equilibrium re-established.

Which of the following statements is correct?
A The concentration of $\mathrm{I}_{2}$ in Y increases.
B The concentration of $I_{2}$ in $Y$ decreases.
C The equilibrium constant increases.
D The equilibrium constant decreases.
13. The order of a reaction

A can only be obtained by experiment
B determines the speed of the overall reaction
C is determined by the stoichiometry involved

D is the sequence of steps in the reaction mechanism.
14. A suggested mechanism for the reaction
$2 \mathrm{X}+\mathrm{Y} \rightarrow \mathrm{X}_{2} \mathrm{Y}$
is a two-step process
$\mathrm{X}+\mathrm{Y} \rightarrow \mathrm{XY}$ (slow)
$\mathrm{XY}+\mathrm{X} \rightarrow \mathrm{X}_{2} \mathrm{Y}$ (fast)
This mechanism is consistent with the rate equation,

A rate $=\mathrm{k}[\mathrm{XY}]$
B rate $=\mathrm{k}[\mathrm{X}][\mathrm{Y}]$
C rate $=\mathrm{k}[\mathrm{X}]^{2}[\mathrm{Y}]$
D rate $=\mathrm{k}[\mathrm{X}][\mathrm{XY}]$.
15. The end-on overlap of two atomic orbitals lying along the axis of a bond leads to

A hybridisation
B a sigma bond
C a pi bond
D a double bond.
16. Which of the following compounds has a geometric isomer?

A


B


C


D


Go to Answers
17. Mandelic acid has two optical isomers $\mathbf{X}$ and $\mathbf{Y}$. The table shows the rotation of plane polarised light caused by various solutions of $\mathbf{X}$ and $\mathbf{Y}$.

| Volume of <br> $\mathbf{0 \cdot 1 \mathbf { m o l ~ 1 ~ } ^ { - 1 }}$ <br> $\mathbf{X} / \mathbf{c m}^{3}$ | Volume of <br> $\mathbf{0 \cdot 1 \mathbf { ~ m o l ~ 1 ~ } ^ { \mathbf { 1 } }}$ <br> $\mathbf{Y / \mathbf { c m } ^ { 3 }}$ | Volume of <br> water/cm | Observed <br> rotation/ |
| :---: | :---: | :---: | :---: |
| 100 | 0 | 0 | +158 |
| 50 | 0 | 50 | +79 |
| 50 | 50 | 0 | 0 |
| 0 | 100 | 0 | -158 |

What would be the observed rotation for a solution containing $25 \mathrm{~cm}^{3} 0 \cdot 1 \mathrm{moll}^{-1} \mathbf{X}$ and $75 \mathrm{~cm}^{3}$ of $0 \cdot 1 \mathrm{moll}^{-1} \mathbf{Y}$ ?

A $-79^{\circ}$
B $-39.5^{\circ}$
C $+39.5^{\circ}$
D $+79^{\circ}$
18. Which of the following is the formula for a tertiary haloalkane?

A $\mathrm{CHBr}_{3}$
B $\left(\mathrm{CH}_{3}\right)_{3} \mathrm{CBr}$
C $\quad\left(\mathrm{CH}_{2} \mathrm{Br}\right)_{3} \mathrm{CH}$
D $\mathrm{BrCH}_{2} \mathrm{C}\left(\mathrm{CH}_{3}\right)_{3}$
19. Propene can be produced by heating 1-bromopropane with ethanolic potassium hydroxide.
This reaction is an example of
A reduction
B hydrolysis
C elimination
D condensation.
20. The formula $\mathrm{C}_{4} \mathrm{H}_{10} \mathrm{O}$ could represent an alcohol $\left(\mathrm{C}_{4} \mathrm{H}_{9} \mathrm{OH}\right)$ or an ether $\left(\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OC}_{2} \mathrm{H}_{5}\right)$.

Which of the following statements would not be true about both compounds?

A They can be made by nucleophilic substitution from a haloalkane.

B They have hydrogen bonds between their molecules.
C They are used as solvents.
D They are flammable.
21. Which of the following will react to form $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OCH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3}$ ?

A $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}$ and $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{COONa}$
B $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{OH}$ and $\mathrm{CH}_{3} \mathrm{COONa}$
C $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{ONa}$ and $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{I}$
D $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{ONa}$ and $\mathrm{CH}_{3} \mathrm{CHICH}_{3}$
22. Which of the following statements is true about the carboxyl group?

A $\quad \mathrm{C}=\mathrm{O}$ and -OH each retain their own properties, unaffected by the other.
B The properties of the $\mathrm{C}=\mathrm{O}$ are changed but the - OH is unaffected.

C The properties of the -OH are changed but the $\mathrm{C}=\mathrm{O}$ is unaffected.
D The properties of the $\mathrm{C}=\mathrm{O}$ and the - OH are each affected by the other.
23. One mole of which of the following compounds will react with the largest volume of $1 \mathrm{moll}^{-1}$ hydrochloric acid?

A $\mathrm{CH}_{3} \mathrm{NHCH}_{3}$
B $\mathrm{H}_{2} \mathrm{NCH}_{2} \mathrm{NH}_{2}$
C $\mathrm{HOOCCH}_{2} \mathrm{NH}_{2}$

D

24. Which of the following structures represents a tertiary amine?

A


B


C


D

25. Which of the following is not an example of a hydrolysis reaction?

A $\mathrm{C}_{2} \mathrm{H}_{4}+\mathrm{H}_{2} \mathrm{O} \rightarrow \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OH}$
B $\mathrm{CH}_{3} \mathrm{CN}+2 \mathrm{H}_{2} \mathrm{O} \rightarrow \mathrm{CH}_{3} \mathrm{COOH}+\mathrm{NH}_{3}$
C $\mathrm{CH}_{3} \mathrm{COOCH}_{3}+\mathrm{H}_{2} \mathrm{O} \rightarrow \mathrm{CH}_{3} \mathrm{COOH}+\mathrm{CH}_{3} \mathrm{OH}$
D $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{COOCH}_{3}+\mathrm{H}_{2} \mathrm{O} \rightarrow \mathrm{C}_{6} \mathrm{H}_{5} \mathrm{COOH}+\mathrm{CH}_{3} \mathrm{OH}$
26. A simplified mass spectrum of an organic compound is shown below.


Which of the following compounds produces this spectrum?

A Propane
B Propan-1-ol
C Propan-2-ol
D Propanone
27. Which of the following analytical techniques depends on the vibrations within molecules?

A Nuclear magnetic resonance spectroscopy
B Atomic emission spectroscopy
C Infra-red spectroscopy
D Mass spectrometry
28. The two isotopes of bromine have mass numbers of 79 and 81 . In the mass spectrum of

the ion fragment with a mass/charge ratio of 92 could be caused by

A $[\mathrm{CHBr}]^{-}$
B $\left[\mathrm{CH}_{2} \mathrm{Br}\right]^{+}$
C $\left[\mathrm{C}_{6} \mathrm{H}_{4} \mathrm{NH}_{2}\right]^{-}$
D $\left[\mathrm{C}_{6} \mathrm{H}_{4} \mathrm{NH}_{2}\right]^{+}$
Go to Answers
29. Which of the following amines shows no infra-red absorption between $3300 \mathrm{~cm}^{-1}$ and $3500 \mathrm{~cm}^{-1}$ ?

A $\left(\mathrm{CH}_{3}\right)_{3} \mathrm{~N}$
B $\mathrm{CH}_{3} \mathrm{NHCH}_{3}$
C $\quad \mathrm{H}_{2} \mathrm{NCH}_{2} \mathrm{NH}_{2}$
D

30. The table shows the structural formulae of some sulfonamides and their antibacterial activity.

| Sulfonamide | Antibacterial activity |
| :---: | :---: |
|  | active |
|  | active |
|  | inactive |
|  | inactive |

Which of the following would be an active antibacterial agent?

A


B


C


D


Candidates are reminded that the answer sheet for Section A MUST be placed INSIDE the front cover of your answer book.

70 marks are available in this section of the paper.

## All answers must be written clearly and legibly in ink.

1. Atomic spectroscopy is a useful analytical tool for identifying and quantifying the elements present in a sample. It also provides information about atomic structure.
(a) When a high voltage is applied to a lamp filled with helium gas, a line of red light, wavelength 706 nm , is observed through a spectroscope.
(i) Explain how the line of red light is produced.
(ii) Calculate the energy, in $\mathrm{kJ} \mathrm{mol}^{-1}$, associated with this wavelength.
(b) A helium atom has two electrons in its ground state. One of the electrons can be described by the four quantum numbers $1,0,0,+1 / 2$.
What four quantum numbers describe the other electron?
(c) (i) Using orbital box notation, write the electronic configuration for a phosphorus atom in its ground state.
(ii) Explain how your answer is consistent with Hund's rule.
(iii) When a phosphorus atom becomes excited an electron can move to the 4 s orbital.

What four quantum numbers describe the excited electron?
(d) Mercury atoms are much larger than those of helium or phosphorus. A small section of the atomic emission spectrum for mercury is shown below.


400 nm
700 nm

Why does this spectrum have multiple lines?
(e) Sir Isaac Newton was thought to have suffered from mercury poisoning and when his hair was analysed the level of mercury was found to be 73 ppm . The unit ppm stands for parts per million and refers to 1 mg per kg .
Calculate the number of moles of mercury in a $1 \cdot 0 \times 10^{-6} \mathrm{~g}$ sample of Newton's hair.
2. The dicarboxylic acid, oxalic acid, has molecular formula $\mathrm{H}_{2} \mathrm{C}_{2} \mathrm{O}_{4}$.

It can be prepared by reacting calcium oxalate with sulfuric acid.

$$
\mathrm{H}_{2} \mathrm{SO}_{4}(\mathrm{aq})+\mathrm{CaC}_{2} \mathrm{O}_{4}(\mathrm{~s})+\mathrm{xH}_{2} \mathrm{O}(\ell) \rightarrow \mathrm{CaSO}_{4} \cdot \mathrm{xH}_{2} \mathrm{O}(\mathrm{~s})+\mathrm{H}_{2} \mathrm{C}_{2} \mathrm{O}_{4}(\mathrm{aq})
$$

(a) Draw a structural formula for oxalic acid.
(b) 4.94 g of $\mathrm{CaSO}_{4} \cdot \mathrm{xH}_{2} \mathrm{O}$ was dehydrated to produce $3 \cdot 89 \mathrm{~g}$ of $\mathrm{CaSO}_{4}$.

Determine the value of x .
(c) The equation for the reaction between oxalic acid solution and sodium hydroxide solution is

$$
\mathrm{H}_{2} \mathrm{C}_{2} \mathrm{O}_{4}(\mathrm{aq})+2 \mathrm{NaOH}(\mathrm{aq}) \rightarrow \mathrm{Na}_{2} \mathrm{C}_{2} \mathrm{O}_{4}(\mathrm{aq})+2 \mathrm{H}_{2} \mathrm{O}(\ell)
$$

A student used a standard solution of $0.0563 \mathrm{moll}^{-1}$ oxalic acid to standardise $20 \cdot 0 \mathrm{~cm}^{3}$ of approximately $0 \cdot 1 \mathrm{moll}^{-1}$ sodium hydroxide solution.
The raw results for the titration are given in the table.

|  | 1st attempt | 2nd attempt | 3rd attempt |
| :--- | :---: | :---: | :---: |
| Final burette reading $/ \mathrm{cm}^{3}$ | $17 \cdot 2$ | $33 \cdot 8$ | $16 \cdot 6$ |
| Initial burette reading $/ \mathrm{cm}^{3}$ | $0 \cdot 0$ | $17 \cdot 2$ | $0 \cdot 1$ |
| Titre $/ \mathrm{cm}^{3}$ | $17 \cdot 2$ | $16 \cdot 6$ | $16 \cdot 5$ |

Calculate the accurate concentration of the sodium hydroxide solution.
(d) Oxalic acid is a primary standard but sodium hydroxide is not. State one characteristic of sodium hydroxide that makes it unsuitable as a primary standard.
f
3. Methane gas can be converted into methanol in a series of steps.

The overall equation for the reaction is

$$
\mathrm{CH}_{4}(\mathrm{~g})+1 / 2 \mathrm{O}_{2}(\mathrm{~g}) \longrightarrow \mathrm{CH}_{3} \mathrm{OH}(\ell)
$$

| Substance | $\Delta \boldsymbol{H}_{\mathbf{f}} \mathbf{} \mathbf{} / \mathbf{k} \mathbf{J ~ \mathbf { m o l } ^ { \mathbf { - 1 } }}$ | $\boldsymbol{S}^{\mathbf{o}} / \mathbf{J ~ K}^{\mathbf{- 1}} \mathbf{~ m o l}^{\mathbf{- 1}}$ |
| :---: | :---: | :---: |
| $\mathrm{CH}_{4}(\mathrm{~g})$ | -75 | 187 |
| $\mathrm{O}_{2}(\mathrm{~g})$ | - | 205 |
| $\mathrm{CH}_{3} \mathrm{OH}(\ell)$ | -239 | 127 |

(a) For the conversion of methane into methanol, calculate
(i) the standard enthalpy change, $\Delta H^{\circ}$
(ii) the standard entropy change, $\Delta S^{\circ}$.
(b) Calculate the maximum temperature above which the reaction becomes no longer feasible.
4. During an Advanced Higher Chemistry Investigation in inorganic chemistry, a student deviates from the planned procedure and produces a pale yellow powder that the teacher suspects might be a new chemical.

Using your knowledge of chemistry suggest what the student might do to determine if it was a brand new substance.
5. An organic acid can be extracted from a reaction mixture using ethoxyethane. $100 \mathrm{~cm}^{3}$ of ethoxyethane were added to $500 \mathrm{~cm}^{3}$ of an aqueous organic acid and the mixture shaken. After being allowed to settle, two immiscible layers formed.
(a) Draw a structural formula for ethoxyethane.
(b) What piece of apparatus would be used to separate both layers?
(c) The following equilibrium was established.

$$
\text { organic acid(aqueous) } \rightleftharpoons \text { organic acid(ethoxyethane) }
$$

$25 \cdot 0 \mathrm{~cm}^{3}$ of the ethoxyethane layer required $22.7 \mathrm{~cm}^{3}$ of $1.10 \mathrm{moll}^{-1} \mathrm{NaOH}$ solution to neutralise it.
$25 \cdot 0 \mathrm{~cm}^{3}$ of the aqueous layer was neutralised by $8.25 \mathrm{~cm}^{3}$ of $0 \cdot 10 \mathrm{moll}^{-1} \mathrm{NaOH}$ solution.
Calculate the equilibrium constant for the system.
6. Aromatic compounds are widely used in the production of pigments, antioxidants and agrochemicals. The reaction sequence below starts with benzene.


The first step in the sequence produces methyl benzene.
(a) Name reagent $\mathbf{A}$.
(b) Identify catalyst $\mathbf{B}$.
(c) What name is given to the type of reaction taking place in both steps?
7. Aspirin is one of the most widely used drugs in our society. Aspirin works as a pain killer by binding to a specific enzyme and blocking its use in biological pathways which lead to the production of pain.
(a) What name is given to drugs that behave in this way?
(b) Aspirin can be prepared by reacting 2-hydroxybenzoic acid $\left(\mathrm{C}_{7} \mathrm{H}_{6} \mathrm{O}_{3}\right)$, with ethanoic anhydride in acidic conditions.

ethanoic anhydride

aspirin
(i) Draw a structural formula for 2-hydroxybenzoic acid.
(ii) The percentage yield for this reaction is $67 \%$.

Calculate the minimum mass of 2-hydroxybenzoic acid required to produce 5.00 g of aspirin?

## [Turn over

8. Methanal is the simplest aldehyde and propenal is the simplest unsaturated aldehyde.
(a) When methanal is reacted with a saturated solution of sodium hydrogensulfite the following product is formed.

(i) Suggest the type of chemical reaction which has taken place.
(b) Some possible reactions of propenal are shown below.

(i) Draw a structural formula for compound $\mathbf{A}$.
(ii) Draw a structural formula for compound $\mathbf{B}$ assuming that propenal reacts with sodium hydrogensulfite in the same way as methanal.
(iii) Which reagent could be used to carry out reaction(3)?
9. Ibuprofen is one of the most commonly used non-steroidal anti-inflammatory drugs (NSAIDs).

The structure of ibuprofen is shown.

(a) Copy the relevant part of the structure of ibuprofen and circle the carbon which makes ibuprofen chiral.
(b) Compounds $\mathbf{A}$ and $\mathbf{B}$, shown below, can be used to manufacture ibuprofen.




An impure sample of ibuprofen known to be contaminated with one of these compounds, was subjected to IR analysis and the major peaks were identified at wavenumbers $1600,1690,1720$ and $3300 \mathrm{~cm}^{-1}$.
(i) Explain which compound is present as an impurity.
(ii) The percentage yield of the final purified product is $57 \%$.

Suggest a reason why the yield is less than $100 \%$
(iii) Suggest how compound $\mathbf{B}$ could be converted into ibuprofen.
10. In the winter of 1987 over a hundred people became extremely ill within hours after dining on cultured blue mussels in restaurants around Prince Edward Island in Canada. After much research, chemists eventually isolated and identified the toxin to be domoic acid, a structural formula of which is shown below.


Using your knowledge of chemistry suggest how domoic acid could be isolated and identified from contaminated mussels.
11. The results of experiments on the alkaline hydrolysis of 2-iodobutane, $\mathrm{CH}_{3} \mathrm{CHIC}_{2} \mathrm{H}_{5}$, are shown in the table below.

The equation for the hydrolysis is

$$
\mathrm{CH}_{3} \mathrm{CHIC}_{2} \mathrm{H}_{5}(\ell)+\mathrm{OH}^{-}(\mathrm{aq}) \rightarrow \mathrm{CH}_{3} \mathrm{CH}(\mathrm{OH}) \mathrm{C}_{2} \mathrm{H}_{5}(\ell)+\mathrm{I}^{-}(\mathrm{aq})
$$

| Experiment | $\left[\mathrm{CH}_{\mathbf{3}} \mathrm{CHIC}_{2} \mathbf{H}_{5}\right] / \mathbf{m o l ~ l}^{\mathbf{- 1}}$ | $\left[\mathrm{OH}^{-}\right] / \mathrm{mol} \mathrm{l}^{\mathbf{- 1}}$ | Initial Rate/mol 1 ${ }^{\mathbf{- 1}} \mathbf{s}^{\mathbf{- 1}}$ |
| :---: | :---: | :---: | :---: |
| 1 | 0.10 | $0 \cdot 10$ | $1.4 \times 10^{-4}$ |
| 2 | 0.20 | 0.20 | $2.9 \times 10^{-4}$ |
| 3 | 0.30 | $0 \cdot 10$ | $4.1 \times 10^{-4}$ |

(a) Determine the order of reaction with respect to
(i) $\mathrm{CH}_{3} \mathrm{CHIC}_{2} \mathrm{H}_{5}$
(ii) $\mathrm{OH}^{-}$.
(b) Using your answers to part (a):
(i) write the rate equation for the reaction;
(ii) calculate a value for the rate constant, k , including the appropriate units.
(c) Using curly arrow notation and your answers to part (a), outline the mechanism for the above reaction.
(d) If the sample of 2-iodobutane contained molecules of only one optical isomer, the product would have no effect on plane-polarised light.

Explain this in terms of the mechanism.
12. To determine the composition of an old coin containing silver, copper and nickel, a student dissolved the coin of mass 10.04 g in nitric acid. The resulting solution was diluted with deionised water to $1000 \mathrm{~cm}^{3}$ in a standard flask.
(a) $0 \cdot 2 \mathrm{moll}^{-1}$ hydrocholoric acid was added to $100 \mathrm{~cm}^{3}$ of this solution until precipitation of silver(I) chloride was complete. After filtration, the precipitate was washed and dried and found to have a mass of 0.620 g .
(i) Calculate the percentage, by mass, of silver in the coin.
(ii) Suggest how the student would test that no silver(I) ions remained in the solution.
(b) The filtrate was treated to reduce the copper(II) ions to copper(I) ions. Ammonium thiocyanate solution was added to precipitate the copper as copper(I) thiocyanate.

$$
\mathrm{Cu}^{+}(\mathrm{aq})+\mathrm{CNS}^{-}(\mathrm{aq}) \rightarrow \mathrm{Cu}^{+} \mathrm{CNS}^{-}(\mathrm{s})
$$

After filtration, drying and weighing, the precipitate was found to weigh 0.320 g . Calculate the percentage, by mass, of copper in the coin.
13. An acidic buffer consists of a solution of a weak acid and one of its salts. This can be prepared by reacting a weak acid with an alkali.
$20.0 \mathrm{~cm}^{3}$ of $1.00 \mathrm{moll}^{-1}$ potassium hydroxide solution was added to $40.0 \mathrm{~cm}^{3}$ of $1.00 \mathrm{moll}{ }^{-1}$ aqueous ethanoic acid forming a buffer solution.
(a) Calculate the concentration of
(i) $\mathrm{K}^{+}(\mathrm{aq})$
(ii) $\mathrm{H}^{+}(\mathrm{aq})$
in the buffer solution.
(b) Explain how this solution would resist change in pH if a few more drops of the potassium hydroxide solution were added.

## 2014 Chemistry

## Advanced Higher (Revised)

## Finalised Marking Instructions

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Part Two: Marking Instructions for each Question

## Section A

| Question | Acceptable Answer(s) |
| :---: | :---: |
| 1 | B |
| 2 | C |
| 3 | C |
| 4 | D |
| 5 | D |
| 6 | B |
| 7 | C |
| 8 | A |
| 9 | A |
| 10 | C |
| 11 | D |
| 12 | B |
| 13 | A |
| 14 | B |
| 15 | B |


| Question | Acceptable Answer(s) |
| :---: | :---: |
| 16 | D |
| 17 | A |
| 18 | B |
| 19 | C |
| 20 | B |
| 21 | C |
| 22 | D |
| 23 | B |
| 24 | A |
| 25 | A |
| 26 | D |
| 27 | C |
| 28 | D |
| 29 | A |
| 30 | A |

## Section B

| Question |  |  | Acceptable answer |  |  |  |  | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | (a) | (i) | An electron is excited/promoted to a higher energy level. <br> When it falls back to a lower/ground state, energy (corresponding to red light) is emitted. |  |  |  |  | 1 | Mention of absorption of light or complementary colours or transmitted light or $\mathrm{d}-\mathrm{d}$ transition = cancelling error (= -1 ) |
| 1 | (a) | (ii) | $\mathrm{E}=\mathrm{Lhc} / \lambda$ or $\mathrm{E}=\mathrm{Lhc} / 1000 \lambda$ or similar correct relationship$\begin{aligned} & =170(169 \cdot 6 / 169 \cdot 60)\left(\mathrm{kJ}^{\left.\left(\mathrm{mol}^{-1}\right)\right)}\right. \\ & 2.82 \times 10^{-22}(\mathrm{~kJ})=1(\mathrm{no} \mathrm{~L}) \end{aligned}$ |  |  |  |  | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ | Wrong units $=-1$ |
| 1 | (b) |  | 1, 0, 0, -1/2 |  |  |  |  | 1 | Wrong order |
| 1 |  | (i) <br> 11 <br> 1s | $11$ | $\frac{11}{2 p}$ <br> (full | 11 <br> ded) or hal | 1 | $\begin{array}{\|l\|} \hline 1 \\ \hline 3 \mathrm{p} \\ \hline \end{array}$ | $1$ | Vertical lines |
| 1 | (c) | (ii) | The (three degenerate) 3p orbitals are filled singly <br> or 3p orbitals are filled in such a way as to maximise the number of parallel spins. |  |  |  |  | 1 |  |
| 1 | (c) | (iii) | $4,0,0,+1 / 2$ or $4,0,0,-1 / 2$ or $4,0,0,1 / 2$ |  |  |  |  | 1 | 0.5 |
| 1 | (d) |  | Many different electron transitions (in the visible region) or many different energy levels. <br> (ignore absorption if penalised already) |  |  |  |  | 1 |  |
| 1 | (e) |  | 73 mg per $\mathrm{kg}=7.3 \times 10^{-2} \mathrm{~g}$ per $10^{3} \mathrm{~g}$ $=\mathbf{7 . 3} \times \mathbf{1 0}^{-11} \mathbf{g}$ of Hg in $10^{-6} \mathrm{~g}$ of hair <br> Number of $\mathrm{mol}=7.3 \times 10^{-11} / 200.6$ $=3.64 \times 10^{-13}(\mathrm{~mol})$ <br> Allow follow through from incorrect number of grams. |  |  |  |  | 1 <br> 1 |  |
|  |  |  |  |  |  |  |  | (11) |  |


| Question |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: |
| 2 | (a) |  <br> $\mathrm{HOOCCOOH} /$ ignore bond angles | 1 | $\mathrm{HO}_{2} \mathrm{CCO}_{2} \mathrm{H}$ Bond from $\mathrm{C}-\mathrm{H}(\mathrm{O})$ $(\mathrm{COOH})_{2}$ |
| 2 | (b) | $\begin{aligned} & \text { Number of moles of } \mathrm{CaSO}_{4}=3 \cdot 89 / 136 \cdot 1 \\ & =0 \cdot 0286 \\ & \text { Number of moles of } \mathrm{H}_{2} \mathrm{O}=1 \cdot 05 / 18 \\ & =0 \cdot 0583 \\ & \text { Value of } \mathrm{x}=2 \end{aligned}$ <br> Must be a whole number. <br> Ignore sig figs in working. | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ | Moles of $\mathrm{CaSO}_{4}$ without $\mathrm{H}_{2} \mathrm{O}$ <br> Moles of $\mathrm{H}_{2} \mathrm{O}$ without $\mathrm{CaSO}_{4}$ |
| 2 | (c) | $\begin{aligned} & \mathrm{n} \text { for oxalic acid }=16.55 \times 10^{-3} \times 0.0563 \\ & =9 \cdot 32 \times 10^{-4} \\ & \\ & \mathrm{c} \text { for } \mathrm{NaOH}=\left(9 \cdot 32 \times 10^{-4} \times 2\right) / 0.020 \\ & =0 \cdot 0932 \mathrm{~mol} \mathrm{l} \\ & 0.093 / 0 \cdot 09318 / 0 \cdot 093177 \\ & \text { If use non concordant }\left(16.77 \mathrm{~cm}^{3}\right) \\ & =0 \cdot 0944 \mathrm{~mol} \mathrm{l}^{-1}=1 \text { mark } \end{aligned}$ | 1 <br> 1 | Wrong or missing units $=-1$ <br> -1 for each error |
| 2 | (d) | Not available in high purity/not stable in solid or solution/solid is deliquescent/hygroscopic/ low gfm/absorbs water/absorbs $\mathrm{CO}_{2}$ | 1 |  |
|  |  |  | (6) |  |


| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3 | (a) | (i) | $-16 \mathrm{~kJ} \mathrm{~mol}^{-1} / \mathrm{kJ}$ or answer in joules | 1 | Capital K = wrong units Lower case j. |
| 3 | (a) | (ii) | $-162.5 \mathrm{~J} \mathrm{~K}^{-1}\left(\mathrm{~mol}^{-1}\right)$ | 1 | -265 |
| 3 | (b) |  | $\left.\begin{array}{l} \Delta \mathrm{G}^{\circ}=\Delta \mathrm{H}^{\circ}-\mathrm{T} \Delta \mathrm{~S}^{\circ}=0 \text { or } \\ \mathrm{T}=\Delta \mathrm{H}^{\circ} / \Delta \mathrm{S}^{\circ} \text { or } \\ \mathrm{T}=\frac{-164000}{-162 \cdot 5} \\ =1009 \mathrm{~K} / 1009 \cdot 2 \mathrm{~K} / 736 \cdot 2^{\circ} \mathrm{C} \end{array}\right]$ <br> Standard state signs not required. <br> 619 K (Follow on from wrong answer in (a)(ii)) <br> $1 \cdot 009$ or 1.01 or $1 \mathrm{~K}=1$ mark <br> Must have correct units. | 1 <br> 1 | Negative value for temperature. Lose one mark. $\begin{aligned} & \Delta \mathrm{G}^{\circ}=\Delta \mathrm{H}^{\circ}-\mathrm{T} \Delta \mathrm{~S}^{\circ} \text { without } 0 \\ & { }^{\circ} \mathrm{K} \text { (Deduct } 1 \text { mark) } \\ & \text { < } 1009.23 \end{aligned}$ |
|  |  |  |  | (4) |  |

Go to Topic Grid


Go to Topic Grid

| Question |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: |
| 5 | (a) |  |  |  |
| 5 | (b) | A separating funnel/separatory funnel/ recognisable diagram. | 1 | Flask (but not cancelling if recognisable diagram) |
| 5 | (c) | n for organic acid (ethoxyethane) in $25 \mathrm{~cm}^{3}$ $=0.0227 \times 1.10=\mathbf{2 . 4 9 7} \times \mathbf{1 0}^{-2} \mathbf{~ m o l} /$ $0.999 \mathrm{~mol} \mathrm{l}^{-1}$ <br> n for organic acid (aqueous) in $25 \mathrm{~cm}^{3}=$ $0.00825 \times 0.10=\mathbf{8 . 2 5} \times \mathbf{1 0}^{-4} \mathbf{~ m o l} /$ $0.033 \mathrm{~mol} \mathrm{l}^{-1}$ $K=\frac{[\text { organic acid }](\text { ethoxyethane })}{[\text { organicacid }](\text { aqueous })}=30 \cdot 3$ <br> $30 \cdot 27$ / $30 / 30 \cdot 267$ <br> $0.033=2$ marks (Inverted $K$ ) <br> Ignore lower case $K$ | 1 | Units $=-1 \mathrm{mark}$ |
|  |  |  | (5) |  |


| Question |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: |
| 6 | (a) | Any correct answer such as chloromethane or correct formula. <br> Bromomethane <br> Iodomethane <br> Methyl chloride etc. <br> Ignore wrong formula. | 1 | Fluoromethane $\mathrm{CH}_{3}{ }^{+}$ <br> Wrong name with correct formula. |
| 6 | (b) | Accept aluminium chloride or iron(III) chloride or aluminium bromide or iron(III) bromide or correct formula. <br> Wrong formula is not a cancelling error. Correct formula but wrong name is not a cancelling error. | 1 | Wrong formula Aluminium oxide |
| 6 | (c) | Electrophilic substitution | 1 | Substitution Nucleophilic |
|  |  |  | (3) |  |


| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7 | (a) |  | Antagonist | 1 | ante |
| 7 | (b) | (i) |  <br> or full structural formula/ Kekule | 1 |  |
| 7 | (b) | (ii) | $\left\{\begin{array}{l} \mathrm{C}_{7} \mathrm{O}_{3} \mathrm{H}_{6} \quad \mathrm{C}_{9} \mathrm{H}_{8} \mathrm{O}_{4} \\ 138 \quad 180 \\ 5 \times \frac{100}{67}=7.463 \mathrm{~g} \\ 138 \rightarrow 180 \\ X \quad \rightarrow 7.463 \quad X=\frac{138 \times 7.463}{180}=5.72 \mathrm{~g} \\ 5.71 \mathrm{~g} / 5.73 \mathrm{~g} / 5.7 \mathrm{~g} \\ 3.83 \mathrm{~g} / 3.8 \mathrm{~g}=2 \text { marks (missing } 67 \%) \\ \mathrm{FT} \text { from incorrect formula mass. } \end{array}\right.$ | $1$ | Deduct mark for missing units. |
|  |  |  |  | (5) |  |


| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 8 | (a) | (i) | Addition ignore nucleophilic/electrophilic | 1 | Sulfonation |
| 8 | (a) | (ii) | Melting point/mixed melting point <br> thin layer chromatography <br> infra-red spectra <br> nmr spectra <br> make a derivative and measure melting point. | 1 | Brady's reagent (any mention of). <br> Mass spectroscopy <br> Spectroscopy <br> Flame tests <br> X-ray crystallography <br> Boiling point |
| 8 | (b) | (i) |  <br> $\mathrm{CH}_{3} \mathrm{CHClCHO}$ <br> Or the 3-chloro product / $\mathrm{CH}_{2} \mathrm{ClCH}_{2} \mathrm{CHO}$ | 1 | $\begin{aligned} & \mathrm{CH}_{3} \mathrm{CHClCOH}_{2} \\ & \mathrm{CH}_{2} \mathrm{ClCH}_{2} \mathrm{COH} \end{aligned}$ |
| 8 | (b) | (ii) |  | 1 | NA |
| 8 | (b) | (iii) | Lithium aluminium hydride/ $\mathrm{LiAlH}_{4}$ <br> Sodium borohydride/sodium <br> tetrahydroborate $/ \mathrm{NaBH}_{4}$ <br> correct name or correct formula $=1$ no cancelling if one correct and one wrong Lithium/Sodium/Potassium aluminium tetrahydride etc. <br> Lithal | 1 | Wrong formula Lithium aluminium anhydride (but ignore if the correct formula is given) |
|  |  |  |  | (5) |  |


| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 9 | (a) |  |  <br> Must show as minimum acceptable the carbon plus the $\mathbf{4}$ different groups attached to it. |  |  |
| 9 | (b) | (i) | A due to the presence of the peak at $1690 \mathrm{~cm}^{-1}$ <br> or <br> A since IR spectrum shows that a ketone is present <br> or <br> A due to $-\mathrm{C}=\mathrm{O}$ stretch at 1690 | 1 | A since IR spectrum shows that an aldehyde is present <br> A since IR spectrum shows that a $\mathrm{C}=\mathrm{O}$ is present <br> 1720 (unless specifying due to ibuprofen) = cancelling |
| 9 | (b) | (ii) | Equilibrium/reversible reaction/side reactions/ losses during purification/crystallisation/ mass transfer losses/mechanical losses/ incomplete/impure reactants. | 1 |  |
| 9 | (b) | (iii) | Some idea of: <br> React with ( $\mathrm{H}, \mathrm{K}$ ) $\mathrm{CN}^{-}$(to increase chain length and replace Br ) or make a nitrile (Acid) hydrolysis of the nitrile (to form a carboxylic acid) or react with (dilute) acid. <br> Make a nitrile followed by hydrolysis $=2$ |  |  |
|  |  |  |  | (5) |  |

Go to Topic Grid


Go to Topic Grid

| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 11 | (a) | (i) | 1 or first | 1 |  |
| 11 | (a) | (ii) | 0 or zero | 1 | No order |
| 11 | (b) | (i) | $\text { Rate }=\mathrm{k}\left[\mathrm{CH}_{3} \mathrm{CHIC}_{2} \mathrm{H}_{5}\right]$ <br> Must follow from answer to (a). | 1 | Do not accept capital K |
| 11 | (b) | (ii) | Accept $(1.37-1.45) \times 10^{-3}$ <br> Units $=\mathrm{s}^{-1}$ <br> $1.4 \times 10^{-3}$ using first line of the table. <br> Follow through from (a) and/or (b) (i) | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ |  |
| 11 | (c) |  | 1 for correct use of curly arrows. <br> Follow through from (a) $-2^{\text {nd }}$ order $-S_{N} 2$ mechanism. <br> Carbocation on its own $=1$ <br> Second line with both reactants and product = 1 <br> Ignore bonds to wrong atoms in carbocation only. <br> Shape of carbocation is not important <br> For $\mathrm{S}_{\mathrm{N}} 2,1$ mark for correct 5-membered transition state with bracket and -ve charge. Dotted bonds not needed. <br> 1 mark = correct reactants and products | 1 <br> 1 <br> 1 | If mechanism does not follow from rate equation $=0$ <br> Intermediate in a bracket with overall charge of + |
| 11 | (d) |  | The $\mathrm{OH}^{-}$ion can attack either side of the carbocation (forming equal quantities of both optical isomers and so a racemic mixture is formed) | 1 | Racemic mixture or similar on its own. <br> It is flat. |
|  |  |  |  | (9) |  |


| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 12 | (a) | (i) | $\begin{aligned} & \mathrm{AgCl} 1 \text { mole }=143.4 \mathrm{~g} \\ & \text { Mass of Ag in } 100 \mathrm{~cm}^{3}= \\ & (107 \cdot 9 / 143 \cdot 4) \times 0.620=\mathbf{0 . 4 6 7} \mathrm{g} \\ & \% \mathrm{Ag} \text { in coin }=(4 \cdot 67 / 10 \cdot 04) \times 100=\mathbf{4 6 . 5} \% \\ & 47 / 46 \cdot 514 / 46 \cdot 51 \\ & (0 \cdot 467 / 10 \cdot 04) \times 100=4.65 \%=1 \end{aligned}$ | 1 <br> 1 |  |
| 12 | (a) | (ii) | Add more HCl , (no more precipitate should form)/add more $\mathrm{Cl}^{-}$ions/add $\mathrm{Br}^{-}$ions/add I ions. <br> Any other reasonable suggestion plus result eg add aldehyde $\rightarrow$ silver mirror | 1 | Add more chlorine Testing conductivity |
| 12 | (b) |  | $\begin{aligned} & \mathrm{CuCNS}, 1 \mathrm{~mol}=121 \cdot 6 \mathrm{~g} \\ & \text { Mass of } \mathrm{Cu} \text { in } 100 \mathrm{~cm}^{3} \\ & =(63 \cdot 5 / 121 \cdot 6) \times 0 \cdot 320=\mathbf{0} \cdot \mathbf{1 6 7} \mathrm{g} \\ & \% \mathrm{Cu} \text { in coin }=(1 \cdot 67 / 10 \cdot 04) \times 100=\mathbf{1 6 \cdot 6} \% \\ & \\ & 17 / 16 \cdot 64 / 16 \cdot 644 \\ & 1 \cdot 66 \%=1 \end{aligned}$ | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ |  |
|  |  |  |  | (5) |  |


| Question |  |  | Acceptable answer | Mark | Unacceptable answer |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 13 | (a) | (i) | $\begin{aligned} & 0.333 \mathrm{~mol}^{-1} \\ & 0.33 \mathrm{~mol}^{-1} / 0.3333 \mathrm{~mol}^{-1} / 0.33333 \mathrm{~mol} \mathrm{1}^{-1} \\ & 1 / 3 \mathrm{~mol} \mathrm{l}^{-1} \end{aligned}$ | 1 | Deduct 1 mark for missing/ wrong units. Recurring 'dot'. $0.3 \mathrm{moll}^{-1}$ |
| 13 | (a) | (ii) | $\begin{aligned} \mathrm{pH} & =\mathrm{pKa}-\log \frac{[\text { acid }]}{[\text { salt }]} \\ & =4.76-\log (0 \cdot 666 / 0.333)=4.46 \\ {\left[\mathrm{H}^{+}\right] } & =10^{-4 \cdot 46}=3.47-3.55 \times 10^{-5} \mathrm{moll}^{-1} \\ 3 \cdot 5 & \times 10^{-5} \mathrm{moll}^{-1} \end{aligned}$ <br> Follow through from incorrect second line. So correct relationship, wrong numbers, correct arithmetic $=2$ marks. [base] in place of [salt]. <br> Acceptable to take a ratio of volumes for second mark. <br> If acid/salt wrong way round $\left(\mathrm{pH} 5 \cdot 06,\left[\mathrm{H}^{+}\right]=\right.$ $8.69-8.71 \times 10^{-6} \mathrm{moll}^{-1}$ ) OR have + , lose first mark but can follow through. <br> 3 marks for correct answer regardless of method used. | $\begin{aligned} & 1 \\ & 1 \\ & 1 \end{aligned}$ | $\begin{aligned} & \text { Wrong relationship = wrong } \\ & \text { principle }=0 \\ & 1 / 2 \text { appearing }=0 \end{aligned}$ |
| 13 | (b) |  | The $\mathrm{OH}^{-}$ions would remove $\mathrm{H}^{+}(\mathrm{aq})$ from the solution OR appropriate equation The $\mathrm{OH}^{-}$ions would react/neutralise the $\mathrm{H}^{+}$. <br> These $\mathrm{H}^{+}(\mathrm{aq})$ ions would be replaced by the dissociation of ethanoic acid molecules into ethanoate and $\mathrm{H}^{+}(\mathrm{aq})$ ions OR appropriate equation with reversible arrow. State symbols not required. | $\begin{aligned} & 1 \\ & 1 \end{aligned}$ | Potassium hydroxide neutralising $\mathrm{H}^{+}$. |
|  |  |  |  | (6) |  |

## X273/13/02

NATIONAL
QUALIFICATIONS 2015

THURSDAY, 28 MAY
$1.00 \mathrm{PM}-3.30 \mathrm{PM}$

## CHEMISTRY <br> ADVANCED HIGHER (REVISED)

Reference may be made to the Chemistry Higher and Advanced Higher Data Booklet.

## SECTION A - 30 marks

Instructions for completion of SECTION A are given on page two.
For this section of the examination you must use an HB pencil.
SECTION B - 70 marks
All questions should be attempted.
Answers must be written clearly and legibly in ink.

1. Infrared radiation can be used in the analysis and identification of organic compounds. Compared to visible radiation, infrared radiation has a

A shorter wavelength and higher frequency
B longer wavelength and lower velocity
C longer wavelength and lower frequency
D shorter wavelength and higher velocity.
2. The diagram shows one of the series of lines in the hydrogen emission spectrum.


## Each line

A represents an energy level within a hydrogen atom
B results from an electron moving to a higher energy level

C lies within the visible part of the electromagnetic spectrum
D results from an excited electron dropping to a lower energy level.
3. The electronic configuration of a krypton atom is

$$
1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{6} 3 d^{10} 4 s^{2} 4 p^{6}
$$

Which of the following ions does not have this configuration?

A $\mathrm{Sr}^{2+}$
B $\quad \mathrm{Se}^{2-}$
C $\mathrm{As}^{3-}$
D $\mathrm{Zr}^{3+}$
4. A Lewis base may be regarded as a substance which is capable of donating an unshared pair of electrons to form a covalent bond.

Which of the following could act as a Lewis base?

A $\mathrm{Co}^{3+}$
B $\mathrm{PH}_{3}$
C $\quad \mathrm{BCl}_{3}$
D $\mathrm{NH}_{4}^{+}$
5. Which line in the table represents the shape and the number of bonding and non-bonding pairs of electrons in the $\mathrm{H}_{3} \mathrm{O}^{+}$ion?

|  | Shape | Bonding <br> pairs | Non-bonding <br> pairs |
| :---: | :---: | :---: | :---: |
| A | tetrahedral | 2 | 2 |
| B | pyramidal | 3 | 1 |
| C | pyramidal | 3 | 0 |
| D | trigonal planar | 3 | 0 |

6. The formula for the tetraamminedichlorocopper(II) complex is

A $\quad\left[\mathrm{Cu}\left(\mathrm{NH}_{3}\right)_{4} \mathrm{Cl}_{2}\right]^{2-}$
B $\quad\left[\mathrm{Cu}\left(\mathrm{NH}_{3}\right)_{4} \mathrm{Cl}_{2}\right]$
C $\quad\left[\mathrm{Cu}\left(\mathrm{NH}_{3}\right)_{4} \mathrm{Cl}_{2}\right]^{2+}$
D $\left[\mathrm{Cu}\left(\mathrm{NH}_{3}\right)_{4} \mathrm{Cl}_{2}\right]^{4+}$.
7. Which of the following would not act as a ligand in the formation of a complex with a transition metal ion?

A $\mathrm{O}^{2-}$
B $\mathrm{NH}_{2} \mathrm{C}_{2} \mathrm{H}_{4} \mathrm{NH}_{2}$
C $\quad \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{NH}_{3}{ }^{+}$
$\mathrm{D} \underset{\mathrm{COO}^{-}}{\mathrm{COO}^{-}}$

Go to Answers
8. What is the co-ordination number of the transition metal in $\left[\mathrm{Co}\left(\mathrm{NH}_{3}\right)_{4}\left(\mathrm{H}_{2} \mathrm{O}\right)_{2}\right] \mathrm{Cl}_{3}$ ?

A 3
B 4
C 6
D 9
9. Which of the following solids would form a colourless aqueous solution?

A $\mathrm{ZnSO}_{4} \cdot 7 \mathrm{H}_{2} \mathrm{O}$
B $\quad \mathrm{NiSO}_{4} \cdot 6 \mathrm{H}_{2} \mathrm{O}$
C $\quad \mathrm{K}_{2} \mathrm{CrO}_{4}$
D $\mathrm{CoCl}_{2}$
10. The stability of a covalent bond is related to its bond order, which can be defined as follows:
bond order $=\frac{1}{2}$ (number of bonding electrons - number of anti-bonding electrons)

The molecular orbital diagram for oxygen is shown. The anti-bonding orbitals are denoted by *.


The bond order for a molecule of oxygen is
A 0
B 1
C 2
D 3 .
11.


The name of the compound shown above is
A 2,3-dimethylpentanoic acid
B 2,3-dimethylhexanoic acid
C 4,5-dimethylhexanoic acid
D 4,5,5-trimethylpentanoic acid.
12. Which of the following compounds will have an enantiomer?

A


B


C


D

13.


Which of the following would be the most likely products of heterolytic bond fission of the above compound?

A


B


C


D

14. Which of the following equations does not involve a nucleophilic substitution?

A


B

$\mathrm{C} \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{Cl}+\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{ONa} \xrightarrow{\text { ethanol }} \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OC}_{2} \mathrm{H}_{5}+\mathrm{NaCl}$
D $\mathrm{C}_{3} \mathrm{H}_{7} \mathrm{Br}+\mathrm{KOH} \xrightarrow{\text { ethanol }} \mathrm{C}_{3} \mathrm{H}_{6}+\mathrm{KBr}+\mathrm{H}_{2} \mathrm{O}$
15. Which of the following reacts with ethanol to form the ethoxide ion?

A $\mathrm{Na}(\mathrm{s})$
B $\quad \mathrm{Na}_{2} \mathrm{O}(\mathrm{s})$
C $\quad \mathrm{NaCl}(\mathrm{aq})$
D $\quad \mathrm{NaOH}(\mathrm{aq})$
16. One of the stages in the preparation of Ibuprofen is shown.


Which of the following reagents could bring about this change?

A HCl
B $\mathrm{LiAlH}_{4}$
C HCN
D $\mathrm{H}_{2} \mathrm{O}$
17. Which of the following compounds will react with both dilute hydrochloric acid and sodium hydroxide solution?

A $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{OH}$
B $\quad \mathrm{C}_{6} \mathrm{H}_{5} \mathrm{NH}_{2}$
C $\mathrm{HOC}_{6} \mathrm{H}_{4} \mathrm{COOH}$
D $\mathrm{H}_{2} \mathrm{NC}_{6} \mathrm{H}_{4} \mathrm{COOH}$
18. Lycopene and $\beta$-carotene are coloured organic compounds found in ripened tomatoes. Both absorb light in the visible region. Lycopene is red and $\beta$-carotene is orange.

Which of the following statements is true about the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) in lycopene and $\beta$-carotene?

A $\beta$-Carotene has a higher energy gap between HOMO and LUMO than lycopene.

B Lycopene has a higher energy gap between HOMO and LUMO than $\beta$-carotene.

C $\beta$-Carotene has the same energy gap between HOMO and LUMO as lycopene.

D The colour of $\beta$-carotene and lycopene is not affected by the energy gap between HOMO and LUMO.
19. The high resolution proton NMR spectrum of compound $\mathbf{X}$ is shown below.

$\mathbf{X}$ could be
A propanal
B propanone
C propan-1-ol
D propanoic acid.

## Go to Topic Grid

20. Which of the following salts will form a solution with the lowest pH ?

A Potassium chloride
B Potassium ethanoate
C Ammonium chloride
D Ammonium ethanoate
21. Which of the following would not be suitable as a buffer solution?

A Boric acid and sodium borate
B Nitric acid and sodium nitrate
C Benzoic acid and sodium benzoate
D Propanoic acid and sodium propanoate
22. The standard entropy of a perfect crystal is zero at

A $\quad 0 \mathrm{~K}$
B $\quad 25 \mathrm{~K}$
C $\quad 273 \mathrm{~K}$
D $\quad 298 \mathrm{~K}$.
23. Which of the following graphs shows the variation in $\Delta G^{\circ}$ with temperature for a reaction which is always feasible?

A $\Delta G^{\circ} /$
$\mathrm{kJ} \mathrm{mol}^{-1}$


B $\Delta G^{\circ} /$ $\mathrm{kJ} \mathrm{mol}{ }^{-1}$


C $\Delta G^{\circ} /$ $\mathrm{kJ} \mathrm{mol}{ }^{-}$


D $\Delta G^{\circ} /$
$\mathrm{kJ} \mathrm{mol}{ }^{-1}$

24. The reaction
$2 \mathrm{SO}_{2}(\mathrm{~g})+\frac{1}{2} \mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 2 \mathrm{SO}_{3}(\mathrm{~g})$
is reversible. After equilibrium has been established the reaction mixture was found to contain 0.2 moles of $\mathrm{SO}_{2}, 0.2$ moles of $\mathrm{O}_{2}$ and 16 moles of $\mathrm{SO}_{3}$.

Which of the following is correct?
A $K>1$ and $\Delta G^{\circ}>0$
B $K>1$ and $\Delta G^{\circ}<0$
C $K<1$ and $\Delta G^{\circ}>0$
D $K<1$ and $\Delta G^{\circ}<0$
25. In a chemical reaction the rate is doubled for every $10^{\circ} \mathrm{C}$ rise in temperature. When the temperature is increased from $20^{\circ} \mathrm{C}$ to $60^{\circ} \mathrm{C}$, the rate of the reaction will become faster by a factor of

A 3
B 4
C 8
D 16 .
26. Two mechanisms have been proposed for the hydrolysis of 2-bromo-2-methylpropane.
One of these has only one step
$\left(\mathrm{CH}_{3}\right)_{3} \mathrm{CBr}+\mathrm{OH}^{-} \rightarrow\left(\mathrm{CH}_{3}\right)_{3} \mathrm{COH}+\mathrm{Br}^{-}$
The other has two steps

$$
\begin{align*}
& \left(\mathrm{CH}_{3}\right)_{3} \mathrm{CBr} \rightarrow\left(\mathrm{CH}_{3}\right)_{3} \mathrm{C}^{+}+\mathrm{Br}^{-} \\
& \left(\mathrm{CH}_{3}\right)_{3} \mathrm{C}^{+}+\mathrm{OH}^{-} \rightarrow\left(\mathrm{CH}_{3}\right)_{3} \mathrm{COH} \tag{Fast}
\end{align*}
$$

(Slow)

The reaction is observed to follow first order kinetics. The rate equation for the overall reaction is
$\mathrm{A} \quad$ rate $=\mathrm{k}\left[\left(\mathrm{CH}_{3}\right)_{3} \mathrm{CBr}\right]$
B rate $=\mathrm{k}\left[\left(\mathrm{CH}_{3}\right)_{3} \mathrm{CBr}\right]\left[\mathrm{OH}^{-}\right]$
$\mathrm{C} \quad$ rate $=\mathrm{k}\left[\left(\mathrm{CH}_{3}\right)_{3} \mathrm{C}^{+}\right]$
D rate $=\mathrm{k}\left[\left(\mathrm{CH}_{3}\right)_{3} \mathrm{C}^{+}\right]\left[\mathrm{OH}^{-}\right]$.
27. Which one of the following is not suitable for the preparation of a primary standard in volumetric analysis?

A Anhydrous sodium carbonate
B Sodium hydroxide
C Oxalic acid
D Potassium iodate
28. The most appropriate pieces of equipment to use when diluting a solution by a factor of 10 would be

A a $10.0 \mathrm{~cm}^{3}$ pipette and a $100 \mathrm{~cm}^{3}$ measuring cylinder
B a $10.0 \mathrm{~cm}^{3}$ pipette and a $50 \mathrm{~cm}^{3}$ standard flask

C a $25.0 \mathrm{~cm}^{3}$ measuring cylinder and a $250 \mathrm{~cm}^{3}$ standard flask
D a $25.0 \mathrm{~cm}^{3}$ pipette and a $250 \mathrm{~cm}^{3}$ standard flask.
29. Using thin-layer chromatography the components of a mixture can be identified by their $\mathrm{R}_{\mathrm{f}}$ values.

Which of the following statements is true about the $R_{f}$ value of an individual component of a mixture?

A The type of stationary phase has no effect on the $R_{f}$ value.
B The polarity of the component has no effect on the $\mathrm{R}_{\mathrm{f}}$ value.
C The composition of the mobile phase has no effect on the $\mathrm{R}_{\mathrm{f}}$ value.
D The distance the solvent front moves has no effect on the $R_{f}$ value.
30. An excess of sodium sulfate was added to a solution of a barium compound to precipitate all the barium ions as barium sulfate, $\mathrm{BaSO}_{4}$. ( GFM of $\mathrm{BaSO}_{4}=233.4 \mathrm{~g}$ ).
How many grams of barium are in 0.458 g of the barium compound if a solution of this sample gave 0.513 g of $\mathrm{BaSO}_{4}$ precipitate?

A $\quad 0.032 \mathrm{~g}$
B $\quad 0.055 \mathrm{~g}$
C $\quad 0.269 \mathrm{~g}$
D $\quad 0.302 \mathrm{~g}$

$$
[E N D \text { OF SECTION } A]
$$

Candidates are reminded that the answer sheet for Section A MUST be placed INSIDE the front cover of your answer book.

70 marks are available in this section of the paper.

## All answers must be written clearly and legibly in ink.

1. (a) A student wrote the following ground state electronic configurations for atoms of beryllium, nitrogen, oxygen and sodium, where 1 denotes an electron.

(i) The three atomic orbitals in the 2 p subshell are said to be degenerate.

What is meant by the term degenerate?
(ii) Explain why the electronic configuration for nitrogen shown above is incorrect.
(iii) Each electron in an atom is described by four quantum numbers.

The table shows the values of the quantum numbers for the 1 s electrons in beryllium.

|  | Quantum number |  |  |  |
| :--- | :---: | :---: | :---: | :---: |
| Electron |  | Principal (n) | Angular momentum(1) | Magnetic (m) |
| Spin (s) |  |  |  |  |
| 1 s | 1 | 1 | 0 | 0 |
| 1 s | $\downarrow$ | 1 | 0 | 0 |

State the values of the 4 quantum numbers for the 3 s electron in sodium.
(b) The first ionisation energy of sodium is $502 \mathrm{~kJ} \mathrm{~mol}^{-1}$.
(i) Calculate the wavelength of light corresponding to this ionisation energy.
(ii) Explain whether visible light would provide sufficient energy to ionise gaseous sodium atoms.
2. Zinc oxide can be reduced to zinc in a blast furnace.

One of the reactions taking place in the furnace is shown.

$$
\mathrm{ZnO}(\mathrm{~s})+\mathrm{CO}(\mathrm{~g}) \rightarrow \mathrm{Zn}(\mathrm{~g})+\mathrm{CO}_{2}(\mathrm{~g})
$$

| Substance | Standard enthalpy of <br> formation, $\Delta \boldsymbol{H}_{\mathbf{f}}^{\mathbf{o}} / \mathbf{k J} \mathbf{m o l}^{\mathbf{- 1}}$ | Standard entropy, <br> $\mathbf{S}^{\circ} / \mathbf{J ~ K}^{\mathbf{- 1}} \mathbf{m o l}^{\mathbf{1}}$ |
| :---: | :---: | :---: |
| $\mathrm{ZnO}(\mathrm{s})$ | -348 | 44 |
| $\mathrm{CO}(\mathrm{g})$ | -110 | 198 |
| $\mathrm{Zn}(\mathrm{g})$ | +130 | 161 |
| $\mathrm{CO}_{2}(\mathrm{~g})$ | -394 | 214 |

For the reduction of zinc oxide with carbon monoxide, use the data in the table to calculate:
(a) the standard enthalpy change, $\Delta H^{\circ}$, in $\mathrm{kJ} \mathrm{mol}^{-1}$;
(b) the standard entropy change, $\Delta S^{\circ}$, in $\mathrm{J} \mathrm{K}^{-1} \mathrm{~mol}^{-1}$;
(c) the theoretical temperature above which the reaction becomes feasible.
3. The active ingredient in aspirin tablets is acetylsalicylic acid, $\mathrm{C}_{9} \mathrm{H}_{8} \mathrm{O}_{4}$. The acetylsalicylic acid content of an aspirin tablet can be determined using a back titration.

Five aspirin tablets were crushed and added to $25.0 \mathrm{~cm}^{3}$ of $1.00 \mathrm{~mol} \mathrm{l}^{-1}$ sodium hydroxide solution. The mixture was heated and allowed to simmer for 30 minutes.


The resulting mixture was allowed to cool before being transferred to a $250 \mathrm{~cm}^{3}$ standard flask and made up to the mark with deionised water.
$25 \cdot 0 \mathrm{~cm}^{3}$ samples of this solution were titrated with $0.050 \mathrm{~mol} \mathrm{l}{ }^{-1}$ sulfuric acid.

$$
2 \mathrm{NaOH}+\mathrm{H}_{2} \mathrm{SO}_{4} \longrightarrow \mathrm{Na}_{2} \mathrm{SO}_{4}+2 \mathrm{H}_{2} \mathrm{O}
$$

The results of the titration are shown in the table.

|  | Rough <br> titration | 1st titration | 2nd titration |
| :--- | :---: | :---: | :---: |
| Initial burette <br> reading/cm |  |  |  |
| Final burette <br> reading/cm | 0.0 | 9.0 | 17.7 |
| Volume <br> used/cm | 9.0 | 17.7 | 26.3 |

(a) What is a back titration?
(b) (i) Calculate the number of moles of sulfuric acid in the average titre.
(ii) Calculate the number of moles of excess sodium hydroxide in the standard flask.
(iii) Calculate the number of moles of sodium hydroxide which reacted with the acetylsalicylic acid.
(iv) The mass of one mole of acetylsalicylic acid is 180 g .

Use this and your answer to part (b)(iii) to calculate the mass of acetylsalicylic acid in one aspirin tablet.
(c) It is good practice to carry out a control experiment.

Suggest a control experiment that could be carried out for this back titration.
4. Sulfa drugs are compounds with antibiotic properties. Sulfa drugs can be prepared from a solid compound called sulfanilamide.
Sulfanilamide is prepared in a six stage synthesis. The equation for the final step in the synthesis is shown.


4-acetamidobenzenesulfonamide sulfanilamide
(a) What type of reaction is this?
(b) The sulfanilamide is separated from the reaction mixture and recrystallised from boiling water.

Why is the recrystallisation necessary?
(c) Calculate the percentage yield of sulfanilamide if $4 \cdot 282 \mathrm{~g}$ of 4 -acetamidobenzenesulfonamide produced 2.237 g of sulfanilamide.
(d) Describe how a mixed melting point experiment would be carried out and the result used to confirm that the product was pure.
(e) Suggest another analytical technique which could be used to indicate whether the final sample is pure.
5. A classic chemistry demonstration involves vanadium changing oxidation states.

Some zinc metal is added to a flask containing an acidified solution of the dioxovanadium $(\mathrm{V})$ ion, $\mathrm{VO}_{2}^{+}(\mathrm{aq})$. The flask is stoppered with some cotton wool and gently swirled. The colour of the solution turns from yellow to blue. Further swirling turns the solution from blue to green. Finally, the flask is shaken vigorously and a violet colour is produced. The observed colours are due to the changing oxidation state of vanadium.

(a) Determine the oxidation number of vanadium in the blue $\mathrm{VO}^{2+}(\mathrm{aq})$ ion.
(b) It was observed during the demonstration that the yellow solution turned green before turning blue in reaction (1).
Suggest a reason for this.
(c) In reaction $3 \mathrm{~V}^{2+}(\mathrm{aq})$ ions are produced.

How many d electrons does a $\mathrm{V}^{2+}(\mathrm{aq})$ ion have?
(d) When the cotton wool stopper is removed the violet solution slowly changes back to blue.

Suggest why this happens.
6. Nitrogen forms a variety of oxides.
(a) Dinitrogen tetroxide, $\mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{~g})$, dissociates to form nitrogen dioxide, $\mathrm{NO}_{2}(\mathrm{~g})$, according to the equation.

$$
\mathrm{N}_{2} \mathrm{O}_{4}(\mathrm{~g}) \quad \rightleftharpoons \quad 2 \mathrm{NO}_{2}(\mathrm{~g})
$$

0.28 mol of $\mathrm{N}_{2} \mathrm{O}_{4}$ gas is placed in an empty 1.00 litre flask and heated to $127^{\circ} \mathrm{C}$. When the system reaches equilibrium, 0.24 mol of $\mathrm{NO}_{2}$ gas is present in the flask.
(i) Calculate the equilibrium constant, K , for the reaction at $127^{\circ} \mathrm{C}$.
(ii) At $25^{\circ} \mathrm{C}$, the numerical value of the equilibrium constant for this reaction is 0.12 . Explain whether the forward reaction is endothermic or exothermic.
(b) Nitrogen monoxide reacts with hydrogen as shown.

$$
2 \mathrm{NO}(\mathrm{~g})+2 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{N}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
$$

In a series of experiments, at a fixed temperature, the initial rates of this reaction were measured.

| Experiment | Initial [NO]/ <br> $\mathbf{m o l ~ 1 ~}$ | Initial [ $\mathbf{H}_{\mathbf{2}}$ ]/ <br> $\mathbf{m o l ~ 1}$ | Initial rate/ <br> $\mathbf{m o l ~ 1 ~}^{-1} \mathbf{s}^{-1}$ |
| :---: | :---: | :---: | :---: |
| 1 | $2 \cdot 00 \times 10^{-3}$ | $1 \cdot 20 \times 10^{-3}$ | $7 \cdot 40 \times 10^{-4}$ |
| 2 | $2 \cdot 00 \times 10^{-3}$ | $2 \cdot 40 \times 10^{-3}$ | $\mathbf{x}$ |
| 3 | $4 \cdot 00 \times 10^{-3}$ | $2 \cdot 40 \times 10^{-3}$ | $\mathbf{y}$ |

The following rate equation was deduced.

$$
\text { Rate }=\mathrm{k}[\mathrm{NO}]^{2}
$$

(i) Using the information above, determine the numerical values for $\mathbf{x}$ and $\mathbf{y}$.
(ii) For experiment 1, calculate the value of the rate constant, k , including the appropriate units.
7. During a lesson students asked their teacher, "What is chemistry all about?" The teacher replied, "Electrons."
Using your knowledge of chemistry, comment on the teacher's response.
8. Phenol is an aromatic compound with the following structure.

(a) What type of hybridisation do the carbon atoms exhibit in phenol?
(b) Phenol takes part in the following reaction.

(i) Suggest a suitable reagent and catalyst for this reaction.
(ii) What type of reaction is taking place?
(c) Phenol can be converted into 2,4,6-trinitrophenol using a mixture of concentrated nitric acid and concentrated sulfuric acid.
(i) Draw a structural formula for 2,4,6-trinitrophenol.
(ii) Write the formula of the reactive species acting on phenol in this reaction.
9. The blue colour of denim jeans comes from a dye known as indigo.


The synthesis of this dye involves a series of complex chemical reactions.
(a) What structural feature of indigo dye allows it to absorb light within the visible region of the electromagnetic spectrum?
(b) Why does a dye, such as indigo, appear blue when viewed in daylight?
(c) Draw a structural formula for the geometric isomer of indigo.
(d) The first step in the synthesis of indigo is the reaction of 2-nitrobenzaldehyde with propanone.

(i) Write the molecular formula for 4-hydroxy-4-(2-nitrophenyl)butan-2-one.
(ii) Suggest the type of chemical reaction taking place during this step of the synthesis.
(e) In the final step of the synthesis, the indigo dye appears as a purple precipitate.

Simple filtration to isolate the precipitate is very slow.
How could the filtration be speeded up?
10. There are four isomers with the molecular formula $\mathrm{C}_{4} \mathrm{H}_{9} \mathrm{Cl}$. Structural formulae for three of these isomers are

$$
\mathrm{CH}_{3} \mathrm{CHClCH}_{2} \mathrm{CH}_{3} \quad\left(\mathrm{CH}_{3}\right)_{2} \mathrm{CHCH}_{2} \mathrm{Cl} \quad\left(\mathrm{CH}_{3}\right)_{3} \mathrm{CCl}
$$

A
B
C
(a) What is the systematic name of isomer $\mathbf{C}$ ?
(b) When refluxed with a solution of potassium hydroxide in ethanol, compound $\mathbf{A}$ undergoes an elimination reaction. Two structural isomers are produced.

Draw a structural formula for each of these two isomers.
(c) Isomer $\mathbf{B}$ reacts with aqueous sodium hydroxide in an $\mathrm{S}_{\mathrm{N}} 2$ reaction.

(i) Name compound $\mathbf{X}$.
(ii) Draw a structure for the transition state in this reaction.
(d) Draw a structural formula for the fourth isomer of $\mathrm{C}_{4} \mathrm{H}_{9} \mathrm{Cl}$.
(e) Low resolution proton NMR spectroscopy can be used to distinguish between isomers $\mathbf{A}, \mathbf{B}$ and $\mathbf{C}$ simply by counting the different numbers of peaks in each spectrum.

How many peaks would be seen in the spectrum of isomer $\mathbf{B}$ ?
(f) Separate solutions of isomers A and B were analysed using plane polarised light. Neither solution showed optical rotation.

For each isomer explain why no optical rotation occurred.
11. (a) One of the main drugs used in the treatment of bird flu is Tamiflu. One step in the synthesis is shown below.


In this reaction, reactant $\mathbf{A}$ has an electrophilic centre and reactant $\mathbf{B}$ has a nucleophilic centre.
(i) Describe how reactant $\mathbf{B}$ is acting as a nucleophile in this reaction.
(ii) Infra-red spectroscopy can be used to identify the product. The infra-red spectrum of the product has a major absorbance peak which is not present in the spectrum of either of the reactants.

In which wave number range, in $\mathrm{cm}^{-1}$, will this absorbance peak be found?
(b) Cimetidine, ranitidine and burimamide are drugs used to counteract the effect of histamine which is known to be involved in the production of acid in the stomach.

histamine

cimetidine

ranitidine

burimamide

Using your knowledge of chemistry suggest how cimetidine, ranitidine and burimamide can counteract the effect of histamine.
12. Compound $\mathbf{X}$ contains only carbon, hydrogen and sulfur.
(a) Complete combustion of $\mathbf{X}$ gave 3.52 g of carbon dioxide, 2.16 g of water and 2.56 g of sulfur dioxide.

Show, by calculation, that the empirical formula of compound $\mathbf{X}$ is $\mathrm{C}_{2} \mathrm{H}_{6} \mathrm{~S}$
(b) The mass spectrum for compound $\mathbf{X}$ is shown below.


Suggest a possible ion fragment which may be responsible for the peak at $\mathrm{m} / \mathrm{z} 47$ in the mass spectrum.
(c) The results of the analysis of the proton NMR spectrum of $\mathbf{X}$ are shown in the table below.

| Peak | Chemical shift/ppm | Relative area under the peak |
| :---: | :---: | :---: |
| 1 | 1.2 | 97 |
| 2 | 1.5 | 32 |
| 3 | 2.4 | 65 |

Considering all the evidence above, draw a structural formula for compound $\mathbf{X}$.

## 2015 Chemistry

## Advanced Higher (Revised)

## Finalised Marking Instructions

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2015 Chemistry Advanced Higher Revised
Part Two: Marking Instructions for each Question
Section A

| Question | Expected Answer(s) | Max Mark |
| :---: | :---: | :---: |
| 1. | C | 1 |
| 2. | D | 1 |
| 3. | D | 1 |
| 4. | B | 1 |
| 5. | B | 1 |
| 6. | B | 1 |
| 7. | C | 1 |
| 8. | C | 1 |
| 9. | A | 1 |
| 10. | C | 1 |
| 11. | C | 1 |
| 12. | B | 1 |
| 13. | A | 1 |
| 14. | D | 1 |
| 15. | A | 1 |


| Question | Expected Answer(s) | Max Mark |
| :---: | :---: | :---: |
| 16. | B | 1 |
| 17. | D | 1 |
| 18. | A | 1 |
| 19. | C | 1 |
| 20. | C | 1 |
| 21. | B | 1 |
| 22. | A | 1 |
| 23. | A | 1 |
| 24. | B | 1 |
| 25. | D | 1 |
| 26. | A | 1 |
| 27. | B | 1 |
| 28. | D | 1 |
| 29. | D | 1 |
| 30. | D | 1 |

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## Section B

| Question |  |  | Acceptable Answer |  | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | a | i | Equal energy/same energy/contains the same energy/ | 1 | Same energy level/same energy subshell/similar energy |
| 1 | a | ii | Correct statement of Hund's Rule. <br> Each orbital should be filled singly before spin pairing takes place <br> The $2 p$ should be filled singly (before spin pairing takes place) <br> The 2 p should be filled singly (before they double up) <br> Orbital box diagram showing correct representation | 1 | "They" should be filled singly <br> Each orbital should be filled singly <br> Breaks Hund's rule |
| 1 | a | iii | $3,0,0,+1 / 2$ or $3,0,0,-1 / 2$ or $3,0,0,1 / 2$, | 1 |  |
| 1 | b | i | $\mathrm{E}=\mathrm{Lhc} / \lambda$ $\begin{align*} & \lambda=6 \cdot 02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3 \times 10^{8} / 502000  \tag{1}\\ & \lambda=238 \cdot 5 \mathrm{~nm}=239 \mathrm{~nm} \text { or } 2.39 \times 10^{-7} \mathrm{~m} \tag{1} \end{align*}$ <br> or $2.385 \times 10^{-7} \mathrm{~m}$ <br> Correct $=3$ sig figs - accept 2 sig figs to 5 sig figs ( 240 nm and 238.52 nm are also acceptable) $238 \mathrm{~nm}=(\mathbf{2})$ <br> Not using $\mathrm{L}=(2)$ if units correct So $3.96 \times 10^{-31} \mathrm{~m}$ or $3.9622 \times 10^{-31} \mathrm{~m}$ or $3.962 \times 10^{-31} \mathrm{~m}$ or $3.96 \times 10^{-22} \mathrm{~nm}$ or $4.0 \times 10^{-31} \mathrm{~m}$ would all get (2) marks If don't convert J to kJ and get $2.39 \times 10^{-4} \mathrm{~m} /$ $2.385 \times 10^{-4} \mathrm{~m} / 23852 \mathrm{~nm} / 24000 \mathrm{~nm}$ then (2) Correct answer with no working $=(\mathbf{3})$ | 3 | $\mathrm{E}=\operatorname{Lhf}($ and nothing else) (0) <br> or $\mathrm{f}=\mathrm{c} / \lambda$ (and nothing else) <br> No units = -1 <br> Mistake in a number $=-1$ <br> Two errors in one line $=-1$ <br> Wrong answer with no working $=0$ (unless the answers are one of those mentioned) |

Go to Topic Grid

| Question |  |  | Acceptable Answer | Max | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1 | b | ii | No - wavelength required is too short. Wavelength required is outside visible range. <br> UV light required / visible light too long wavelength / frequency of visible light too low / visible light is between $400-700 \mathrm{~nm} / 239 \mathrm{~nm}$ is not in the visible region <br> If calculated waveength in part (i) is in the range $400-700 \mathrm{~nm}$ then follow through answer " yes" with correct explanation $=(\mathbf{1})$ | 1 | No with no explanation. <br> Visible light (energy) not enough <br> No with wrong range of visible light $=(\mathbf{0})$ <br> No because visible light is not correct wavelength / energy. <br> Any mention of energy with no explanation $=(\mathbf{0})$ |
|  |  |  |  | (7) |  |
| 2 | a |  | $\Delta \mathrm{H}^{\circ}=194$ | 1 | -194 |
| 2 | b |  | $\Delta S^{\circ}=133$ | 1 | $-133 / 0 \cdot 133$ |
| 2 | c |  | $\begin{gather*} \Delta \mathrm{G}^{\circ}=\Delta \mathrm{H}^{\circ}-\mathrm{T} \Delta \mathrm{~S}^{\circ}=0 \text { or } \mathrm{T}=\frac{\Delta \mathrm{H}^{\circ}}{\Delta \mathrm{S}^{\circ}}  \tag{1}\\ =\frac{194000}{133}=1458 \cdot 6 \mathrm{~K} \text { or } 1459 \mathrm{~K} \end{gather*}$ <br> Or $1460 \mathrm{~K} / 1186{ }^{\circ} \mathrm{C} / 1185 \cdot 6{ }^{\circ} \mathrm{C}$ <br> Allow 3 to 5 sig figs <br> Follow through from incorrect (a) and (b) $194 / 133=(\mathbf{1})$ <br> Standard symbols not needed for first mark | 2 | Deduct 1 mark for ${ }^{\circ} \mathrm{K}$ or for - ve value for temp <br> 1458 K, 1458, $1500 \mathrm{~K}, 1458.65$ <br> K are only worth 1 mark if correct relationship given |
|  |  |  |  | (4) |  |


| Question |  |  | Acceptable Answer | Max | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3 | a |  | Correct answers along the lines of: When excess reagent is added (to analyte). Then the excess reagent is titrated with $2^{\text {nd }}$ reagent. <br> or <br> Tablet added to excess NaOH . The titration shows the volume of NaOH left unreacted by the tablet. <br> or <br> A known quantity of either an acid or base is reacted with an unknown quantity of some chemical. How much leftover acid or base remaining can be determined via titration and so how much of it reacted with the other chemical can be worked out to determine the chemical's concentration. <br> or <br> It is when a substance is not titrated itself but instead a compound is reacted with the substance and then the remaining compound is titrated to see how much did not react ie how much was left over. | 1 | Back titration is used when one of the substances used is insoluble in water. In this case the aspirin tablet is insoluble therefore back titration is used. |
| 3 | b | i | $\begin{gathered} \mathrm{mol} \mathrm{H}_{2} \mathrm{SO}_{4}=8.65 / 1000 \times 0.050 \\ =4.325 \times 10^{-4} \\ 4.3 \times 10^{-4} \text { or } 4.33 \times 10^{-4} \\ (8 \cdot 6 / 1000 \times 0.050=(\mathbf{1})) \end{gathered}$ | 1 | $\begin{aligned} & 4.0 \times 10^{-4} \\ & 4.35 \times 10^{-4} \end{aligned}$ |
| 3 | b | ii | Mol NaOH in $25 \mathrm{~cm}^{3}$ sample $=8.65 \times 10^{-4} \mathrm{~mol}$ mol NaOH in $250 \mathrm{~cm}^{3}$ standard flask $=8.65 \times 10^{-3}(0.00865 \mathrm{~mol}) / 8.7 \times 10^{-3}$ <br> Follow on $=20 \times$ answer to part (i) | 1 |  |
| 3 | b | iii | Initial moles of NaOH $=25 / 1000 \times 1=0.025 \mathrm{~mol}$ <br> Moles of NaOH reacting with ASA $\begin{aligned} & =0.025-0.00865=0.01635 \\ & =0.01635 / 0.016 / 0.0164 \end{aligned}$ <br> Accept 0.0163 as follow on from 8.7 | 1 |  |

Go to Topic Grid

| Question |  |  | Acceptable Answer |  | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3 | b | iv | Moles of ASA $=0.01635 / 2=0.008175$ <br> Mass of ASA $0.008175 \times 180=1.4715 \mathrm{~g}(\mathbf{1})$ <br> Mass of ASA in one tablet $=0.2943 \mathrm{~g}$ <br> 0.29 / 0.294 / 0.2952 / 0.295 / 0.3 or converted to mg <br> Allow follow through from any answer in (iii) 1mark for $90 \times$ answer to part (iii) <br> 2 marks for 18 x answer to part (iii) | 2 |  |
| 3 | c |  | Repeat the experiment with pure / analar ASA Use known quantity of aspirin / ASA | 1 | Answer in terms of a 'blank' (no aspirin) or standardisation of NaOH or $\mathrm{H}_{2} \mathrm{SO}_{4}$ |
|  |  |  |  | (7) |  |

Go to Topic Grid

| Question |  | Acceptable Answer | Max | Unacceptable |
| :---: | :---: | :---: | :---: | :---: |
| 4 | a | Hydrolysis /Acid hydrolysis | 1 | alkaline |
| 4 | b | To purify (the sulfanilamide) <br> To get rid of impurities <br> To make purer | 1 | To improve the \% yield |
| 4 | c | GFM reactant $214 \cdot 1$, GFM product $172 \cdot 1$ <br> Both GFM calculated correctly $4 \cdot 282 / 214 \cdot 1 \times 172 \cdot 1=3 \cdot 442$ $\begin{equation*} 2.237 / 3 \cdot 442 \times 100=65 \% \tag{1} \end{equation*}$ <br> Acceptable - 64.9913, 64.991, 64.99, $65 \cdot 0$ or $\begin{equation*} 4 \cdot 282 / 214 \cdot 1=0 \cdot 02 \text { moles } \times 172 \cdot 1=3 \cdot 442 \tag{2} \end{equation*}$ <br> Then $\begin{equation*} 2 \cdot 237 / 3 \cdot 442 \times 100=65 \% \tag{1} \end{equation*}$ | 3 | $64 \cdot 9$ (wrong rounding) |
| 4 | d | The sample is mixed with pure sulfanilimide / substance <br> The melting point of the mixture will be the same (as pure sulfanilimide if the sample is pure) | 2 |  |
| 4 | e | (Thin layer) chromatography/IR/NMR/TLC | 1 |  |
|  |  |  | (8) |  |


| Question |  | Acceptable Answer | Max <br> Mark | Unacceptable |
| :---: | :---: | :--- | :--- | :--- |
| $\mathbf{5}$ | $\mathbf{a}$ |  | (IV), 4, +4, IV, 4+, four | $\mathbf{1}$ |
| $\mathbf{5}$ | $\mathbf{b}$ |  | $4 / 4-$ |  |
| Both the blue / VO ${ }^{2+}$ and yellow / $\mathrm{VO}_{2}{ }^{+}$ <br> coloured (ions) are present (and will produce <br> the green colour) / yellow and blue gives <br> green | $\mathbf{1}$ | Green is an intermediate colour <br> between blue and yellow. |  |  |
| $\mathbf{5}$ | $\mathbf{c}$ |  | $3 /$ three | $\mathbf{1}$ |
| $\mathbf{5}$ | $\mathbf{d}$ |  | (Oxygen) oxidises the vanadium ions / reacts <br> with oxygen / oxygen turns it back / oxygen <br> effects the mixture / oxidation of $\mathrm{V}^{2+}$ ion / <br> reacts with air to oxidised form / it has been <br> oxidised | $\mathbf{1}$ |


| Question |  |  | Acceptable Answer | $\begin{gathered} \text { Max } \\ \text { Mark } \\ \hline \\ \hline 3 \end{gathered}$ | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6 | a | i | At equilibrium $\left[\mathrm{NO}_{2}\right]=0.24 \mathrm{~mol} \mathrm{l}^{-1}$ $\mathrm{N}_{2} \mathrm{O}_{4}$ reacted $\rightarrow 0 \cdot 24 / 2=0 \cdot 12$ <br> [ $\mathrm{N}_{2} \mathrm{O}_{4}$ ] at equilibrium $\begin{equation*} \rightarrow 0 \cdot 28-0 \cdot 12=0 \cdot 16 \tag{1} \end{equation*}$ <br> $\mathrm{K}=\left[\mathrm{NO}_{2}\right]^{2} /\left[\mathrm{N}_{2} \mathrm{O}_{4}\right]$ or $\begin{equation*} =(0 \cdot 24)^{2} /(0 \cdot 16) \tag{1} \end{equation*}$ $\begin{equation*} =0.36 \tag{1} \end{equation*}$ <br> Correct FT from incorrect (or missing $0 \cdot 16$ ) <br> For example $0.24^{2} / 0.28=0.206 / 0.21 / 0.2$ <br> $0 \cdot 24^{2} / 0 \cdot 12=0.48$ |  | $0 \cdot 24^{2} / 0 \cdot 28 \times 127=0$ marks <br> 1 mark deducted if units given |
| 6 | a | ii | The forward reaction is endothermic since decreasing the temp has favoured the reverse reaction. <br> The forward reaction is endothermic with an acceptable reason that shows an understanding of degree of dissociation (eg more product forms at higher temperatures / as temp decreases the yield decreases). <br> or <br> There is bond breaking taking place therefore the reaction is endothermic. <br> Correct FT from (i) | 1 | Reaction is endothermic because as temperature decreases K decreases |
| 6 | b | i | $\begin{align*} & x=7.40 \times 10^{-4} / 7.4 \times 10^{-4}  \tag{1}\\ & y=2.96 \times 10^{-3} / 3.0 \times 10^{-3} \tag{1} \end{align*}$ | 2 | $3 \times 10^{-3}$ |
| 6 | b | ii | $\begin{align*} & \text { Rate }=\mathrm{k}[\mathrm{NO}]^{2} \\ & \qquad \mathrm{k}=\frac{7 \cdot 40 \times 10^{-4}}{\left(2 \cdot 00 \times 10^{-3}\right)^{2}}=185  \tag{1}\\ & \quad 1 \mathrm{~mol}^{-1} \mathrm{~s}^{-1} \tag{1} \end{align*}$ <br> (units in any order eg $\mathrm{mol}^{-1} \mathrm{ls}^{-1}$ ) <br> if unit is incorrect lose one mark | 2 |  |
|  |  |  |  | (8) |  |



\begin{tabular}{|c|c|c|c|c|c|}
\hline \multicolumn{3}{|l|}{Question} \& Acceptable Answer \& Max \& Unacceptable <br>
\hline 8 \& a \& \& $\mathrm{sp}^{2}$ \& 1 \& <br>
\hline 8

8 \& b

b \& ii \& | Chloromethane / methylchloride bromomethane / methylbromide and $\mathrm{FeCl}_{3}$ / $\mathrm{FeBr}_{3} / \mathrm{AlCl}_{3} / \mathrm{AlBr}_{3} /$ iron chloride / iron bromide Reagent and catalyst needed for mark |
| :--- |
| Electrophilic substitution / alkylation / Friedel Crafts | \& \[

1
\]

\[
1

\] \& | $\mathrm{CCl}_{4} / \mathrm{FeCl} / \mathrm{FeCl}_{2} /$ iron(ii) chloride |
| :--- |
| Nucleophilic substitution | <br>


\hline 8 \& c \& i \& |  |
| :--- |
| Kekule structure is fine |
| Must have correct placing of bonds to nitro groups | \& 1 \& Bonds from benzene ring going to O of the nitro group <br>

\hline 8 \& c \& ii \& $\mathrm{NO}_{2}{ }^{+}$ \& 1 \& $$
\begin{aligned}
& \mathrm{NO}^{2+} \\
& \mathrm{H}_{2} \mathrm{SO}_{4} / \mathrm{HNO}_{3}
\end{aligned}
$$ <br>

\hline \& \& \& \& (5) \& <br>
\hline
\end{tabular}

Go to Topic Grid

| Question |  |  | Acceptable Answer | Max | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 9 | a |  | Alternating single double bonds/conjugated system | 1 | Delocalised electrons chromophore |
| 9 | b |  | An answer such as red and green being absorbed (and blue being transmitted) / absorbs all colours except blue / orange absorbed / red and yellow absorbed | 1 | Reflects - cancelling Blue light emitted - cancelling General answer in terms of absorption and transmittance |
| 9 | c |  |  <br> Non - skeletal <br> Circled part most important - NH on same side with $\mathrm{C}=\mathrm{O}$ on opposite. | 1 |  |
| 9 | d | i | $\mathrm{C}_{10} \mathrm{H}_{11} \mathrm{NO}_{4}$ - any order of atoms but must be molecular | 1 |  |
| 9 | d | ii | Addition <br> Ignore electrophilic and nucleophilic | 1 |  |
| 9 | e |  | Suction / vacuum filtration / fluted filter paper / using Büchner / Hirsch / sintered glass / water pump / aspirator | 1 |  |
|  |  |  |  | (6) |  |

Go to Topic Grid

| Question |  |  | Acceptable Answer |  | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10 | a |  | 2-chloro-2-methylpropane <br> 2-chloromethylpropane | 1 | 2,2 methylchloropropane methyl-2-chloropropane 2-methylchloropropane |
| 10 | b |  | $\mathrm{CH}_{3} \mathrm{CH}=\mathrm{CHCH}_{3}$ (1) and $\mathrm{CH}_{2}=\mathrm{CHCH}_{2} \mathrm{CH}_{3}$ (1) Or full structural formulae Ignore incorrect names | 2 | Names only |
| 10 | c | i | 2-methylpropan-1-ol <br> Methylpropan-1-ol <br> 1-hydroxy-2-methylpropane <br> Methyl-1-propanol | 1 | 2-methylprop-1-ol |
| 10 | c | ii | Five membered transition state with negative charge <br> Needs dotted bonds as above <br> Wedges and dotted 3D bonds are OK. | 1 | OH---- (dotted bond going to H of OH ) |
| 10 | d |  | $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{Cl}$ <br> Or full structural / skeletal | 1 |  |
| 10 | e |  | 3 / three | 1 |  |
| 10 | f |  | $\mathrm{A}=$ (has an asymmetric carbon and so) must be a racemic mix (1) B = no chiral (carbon) / no carbon with four different groups around it (1) | 2 | Carbon does not have four molecules around it Carbon does not have four atoms around it B does not have an optical isomer |
|  |  |  |  | (9) |  |

Go to Topic Grid

| Question |  |  | Acceptable Answer |  | Unacceptable |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 11 | a | i | Must mention "lone pair of electrons on the N " / non-bonded pair of electrons on $\mathrm{N} /$ lone pair of electrons on the amine / nitrogen donates electrons to reactant $\mathrm{A} /$ the $\mathrm{NH}_{2}$ has a lone pair of electrons <br> nitrogen or amine must be mentioned | 1 | Nitrogen is a nucleophile $\mathrm{N}-\mathrm{H}$ bond is polar which causes the N to be slightly negative causing it to act as a nucleophile |
| 11 | a | ii | 3570-3200 | 1 | Ignore units |
| 11 | b |  | This is an open ended question <br> 1 mark: The student has demonstrated a limited understanding of the chemistry involved. The student has made some statement(s) which is/are relevant, showing that at least a little of the relevant chemistry is understood. <br> 2 marks: The student has demonstrated a reasonable understanding of the chemistry involved. The student makes some statements which are relevant showing understanding of the problem. <br> 3 marks: The maximum available mark would be awarded to a student who has demonstrated a good understanding of the chemistry involved. The student has shown a good understanding of the chemistry involved and has provided a logically correct answer to the question asked. This type of response might include a statement of the principles involved, a relationship or an equation and an application of these to answer the question. This does not mean that the answer has to be what might be termed an 'excellent' or 'complete' answer | 3 | The student has demonstrated no understanding of the chemistry involved. There is no evidence that the student has recognised the area of chemistry involved or has given any statement of a relevant chemistry principle. This mark would also be given when the student merely restates the chemistry given in the question. |
|  |  |  |  | (5) |  |

Go to Topic Grid


WEDNESDAY, 18 MAY
9:00 AM - 11:30 AM

Instructions for the completion of Section 1 are given on Page 02 of your question and answer booklet X713/77/01.

Record your answers on the answer grid on Page 03 of your question and answer booklet.
Reference may be made to the Chemistry Higher and Advanced Higher Data Booklet.
Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## SECTION 1-30 marks

## Attempt ALL questions

1. Which of the following lists electromagnetic radiation bands in order of increasing wavelength?

A X-ray, infrared, ultraviolet, radio
B Infrared, ultraviolet, X-ray, gamma
C Ultraviolet, visible, infrared, radio
D Radio, infrared, visible, gamma
2. Which of the following states that electrons fill orbitals in order of increasing energy?

A Hund's rule
B The aufbau principle
C The Pauli exclusion principle
D The valence shell electron pair repulsion theory
3.


In the periodic table outlined above, one area is marked X . Moving across area X , from one element to the next, the extra electron usually occupies an orbital of type

A s
B p
C d
D f.
4. Which of the following molecules contains three atoms in a straight line?

A $\quad \mathrm{BF}_{3}$
B $\mathrm{CH}_{4}$
C $\mathrm{H}_{2} \mathrm{O}$
D $\mathrm{SF}_{6}$
5. The complex ion $\left[\mathrm{Cu}(\mathrm{CN})_{6}\right]^{4-}$ is called

A hexacyanocopper(II)
B hexacyanocopper(IV)
C hexacyanocuprate(II)
D hexacyanocuprate(IV).
6. $\mathrm{HCN}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons \mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})+\mathrm{CN}^{-}(\mathrm{aq})$

In the above equation $\operatorname{HCN}(\mathrm{aq})$ is acting as
A an acid
B a conjugate acid
C a base
D a conjugate base.
7. The use of an indicator is not appropriate in titrations involving

A hydrochloric acid solution and methylamine solution
B nitric acid solution and potassium hydroxide solution
C methanoic acid solution and ammonia solution
D propanoic acid solution and sodium hydroxide solution.
8. Which of the following can produce a buffer solution when added to aqueous $\mathrm{NH}_{4} \mathrm{Cl}$ ?

A Ammonia
B Ethanoic acid
C Potassium chloride
D Ammonium sulfate
9. Which of the following reactions cannot be described as an enthalpy of formation?

A $\quad \mathrm{Si}(\mathrm{s})+4 \mathrm{Cl}(\mathrm{g}) \rightarrow \mathrm{SiCl}_{4}(\mathrm{l})$
B $\mathrm{Mg}(\mathrm{s})+1 / 2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{MgO}(\mathrm{s})$
C $\mathrm{C}(\mathrm{s})+2 \mathrm{H}_{2}(\mathrm{~g})+1 / 2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CH}_{3} \mathrm{OH}(\mathrm{l})$
D $2 \mathrm{C}(\mathrm{s})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{C}_{2} \mathrm{H}_{6}(\mathrm{~g})$
10. Which of the following is likely to have the lowest standard entropy at $100^{\circ} \mathrm{C}$ ?

A Neon
B Mercury
C Sulfur
D Phosphorus
11. For the reaction
$2 \mathrm{~A}+2 \mathrm{~B} \rightarrow \mathrm{C}$
the rate equation is
rate $=k[A][B]^{2}$.
Which of the following could be a possible mechanism for this reaction?
A $\quad \mathrm{A}+\mathrm{B} \rightarrow \mathrm{X} \quad$ (fast)
$X+A+B \rightarrow C$ (slow)
B $A+2 B \rightarrow X$ (slow)
$X+A \rightarrow C \quad$ (fast)
C $\quad 2 A+B \rightarrow X$ (slow)
$X+B \rightarrow C \quad$ (fast)
D $\quad 2 \mathrm{~A}+\mathrm{B} \rightarrow \mathrm{X}$ (fast)
$X+B \rightarrow C$
(slow)
12. Which line in the table has the correct number and type of bonds in the structure shown?


|  | Number of $\sigma$-bonds | Number of $\pi$-bonds |
| :---: | :---: | :---: |
| A | 2 | 18 |
| B | 4 | 16 |
| C | 16 | 4 |
| D | 18 | 2 |

13. 5-Methylhept-3-ene-2-one is an aroma molecule found in some types of tea.

Which of the following shows a structural formula for the trans-isomer of 5-methylhept-3-ene-2-one?

A


B


C


D

14. Which of the following does not exhibit hydrogen bonding between its molecules?

A Ethanol
B Ethylamine
C Ethanoic acid
D Ethoxyethane
15. In the homologous series of amines, an increase in chain length is accompanied by

|  | Volatility | Solubility in water |
| :---: | :---: | :---: |
| A | increased | increased |
| B | decreased | decreased |
| C | increased | decreased |
| D | decreased | increased |

16. Which of the following will react together to produce 2-ethoxypropane?

A $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}$ and $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{COONa}$
B $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{ONa}$ and $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{Br}$
C $\mathrm{CH}_{3} \mathrm{CH}(\mathrm{OH}) \mathrm{CH}_{3}$ and $\mathrm{CH}_{3} \mathrm{COONa}$
D $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{ONa}$ and $\mathrm{CH}_{3} \mathrm{CHBrCH}_{3}$
17. Aldehydes can be converted into alcohols by the reaction shown


Which of the following aldehydes would produce a primary alcohol?
A Methanal
B Ethanal
C Propanal
D Butanal
18. $\mathrm{CH}_{3} \mathrm{CHO}+\mathrm{NH}_{2} \mathrm{NH}_{2} \rightarrow \mathrm{CH}_{3} \mathrm{CH}=\mathrm{NNH}_{2}+\mathrm{H}_{2} \mathrm{O}$

This reaction is an example of
A hydration
B hydrolysis
C dehydration
D condensation.
19. When but-1-ene reacts with hydrogen chloride, 1-chlorobutane and 2-chlorobutane are formed. According to Markovnikov's rule

A there will be more 2-chlorobutane than 1-chlorobutane
B there will be more 1-chlorobutane than 2-chlorobutane
C there will be equal proportions of both products
D it is impossible to tell the relative proportion of each product.
20. When 2-bromobutane reacts with ethanolic potassium cyanide and the compound formed is hydrolysed with dilute acid, the final product is

A butanoic acid
B pentanoic acid
C 2-methylbutanoic acid
D 2-methylpentanoic acid.
21.


Which line in the table correctly identifies $\mathrm{W}, \mathrm{X}, \mathrm{Y}$ and Z in the reaction sequence?
$\mathbf{W} \xrightarrow{\text { reduction }} \mathbf{X} \xrightarrow{\text { dehydration }} \mathbf{Y} \xrightarrow{\text { addition }} \mathbf{Z}$

|  | $W$ | $X$ | $Y$ | $Z$ |
| :---: | :---: | :---: | :---: | :---: |
| A | 1 | 4 | 2 | 3 |
| B | 3 | 2 | 1 | 4 |
| C | 3 | 2 | 4 | 1 |
| D | 4 | 1 | 2 | 3 |

22. Which of the following statements about benzene is not true?

A It is planar.
B It is susceptible to attack by electrophilic reagents.
C Its carbon to carbon bonds are equal in length.
D It is readily attacked by bromine.
23. $\left(\mathrm{CH}_{3}\right)_{3} \mathrm{CBr}+\mathrm{OH}^{-} \rightarrow\left(\mathrm{CH}_{3}\right)_{3} \mathrm{COH}+\mathrm{Br}^{-}$

The above reaction proceeds via an $\mathrm{S}_{\mathrm{N}} 1$ mechanism.
What effect will doubling the concentration of hydroxide ions have on the reaction rate?
A It will have no effect.
B The reaction rate will halve.
C The reaction rate will double.
D The reaction rate will increase by a factor of four.
24.


Which of the following shows the splitting pattern for the circled H atom above, in a high resolution proton NMR spectrum?

A


B


C


D

25.



Amphetamine

Noradrenaline and phenylephrine stimulate receptors in the body resulting in increased blood pressure. Amphetamine has the same effect but works indirectly in the body by stimulating production of noradrenaline.
The structural fragment acting directly on the receptor is
A

B

C

D

26. In a UK workplace, the maximum short-term exposure limit for carbon monoxide is 200 ppm in a 15 minute period.
If a person breathes in 134 g of air in a 15 minute period, what is the mass of carbon monoxide breathed in at the maximum short-term exposure limit?

A $\quad 1.49 \mathrm{mg}$
B $\quad 26.8 \mathrm{mg}$
C $\quad 1.49 \mathrm{~g}$
D 26.8 g
27. Sodium hydroxide is unsuitable for use as a primary standard because it

A is corrosive
B is readily soluble in water
C is available in a high degree of purity
D readily absorbs water from the atmosphere.
28. What volume of $0.25 \mathrm{moll}^{-1}$ calcium nitrate is required to make, by dilution with water, $500 \mathrm{~cm}^{3}$ of a solution with a nitrate ion concentration of $0 \cdot 1 \mathrm{moll}^{-1}$ ?

A $\quad 50 \mathrm{~cm}^{3}$
B $\quad 100 \mathrm{~cm}^{3}$
C $200 \mathrm{~cm}^{3}$
D $400 \mathrm{~cm}^{3}$
29. 1.60 g of an anhydrous metal sulfate were dissolved in water. Addition of excess barium chloride solution resulted in the precipitation of $2 \cdot 33 \mathrm{~g}$ of barium sulfate.
The original substance was
A copper(II) sulfate
B magnesium sulfate
C sodium sulfate
D calcium sulfate.
30. 0.020 moles of the salt $\mathrm{Pt}\left(\mathrm{NH}_{3}\right)_{\mathrm{x}} \mathrm{Cl}_{2}$ required $20.0 \mathrm{~cm}^{3}$ of $4.0 \mathrm{moll}^{-1}$ nitric acid to react completely with the $\mathrm{NH}_{3}$ ligands.
The value of $x$ is
A 2
B 4
C 6
D 8 .
[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

## SECTION 2-70 marks

Attempt ALL questions

1. Ethene can be hydrated to produce ethanol.

$$
\mathrm{C}_{2} \mathrm{H}_{4}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightarrow \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OH}(\ell)
$$

| Compound | Standard free energy of <br> formation, $\Delta G^{\circ}\left(\mathrm{kJ} \mathrm{mol}^{-1}\right)$ | Standard enthalpy of <br> formation, $\Delta H^{\circ}\left(\mathrm{kJ} \mathrm{mol}^{-1}\right)$ |
| :---: | :---: | :---: |
| Ethene | 68 | 52 |
| Water | -237 | -286 |
| Ethanol | -175 | -278 |

(a) For the hydration of ethene, use the data in the table to calculate:
(i) the standard enthalpy change, $\Delta \mathrm{H}^{\circ}$, in $\mathrm{kJ} \mathrm{mol}^{-1}$;
(ii) the standard entropy change, $\Delta S^{\circ}$, in $\mathrm{J} \mathrm{K}^{-1} \mathrm{~mol}^{-1}$.
(b) Calculate the temperature, in K , at which this reaction just becomes feasible.
2. In the periodic table, period 2 is comprised of the elements lithium to neon.

The following table shows two of the quantum numbers for all ten electrons in a neon atom.

| Electron | Principal <br> quantum number, $n$ | Angular momentum <br> quantum number, $l$ |
| :---: | :---: | :---: |
| 1 | 1 | 0 |
| 2 | 1 | 0 |
| 3 | 2 | 0 |
| 4 | 2 | 0 |
| 5 | 2 | 1 |
| 6 | 2 | 1 |
| 7 | 2 | 1 |
| 8 | 2 | 1 |
| 9 | 2 | 1 |
| 10 |  | 1 |

(a) Write the electronic configuration for neon in terms of s and p orbitals.
(b) The angular momentum quantum number, $l$, is related to the shape of an orbital.

Draw the shape of an orbital when $l$ has a value of 1 .
(c) The magnetic quantum number, $m$, is related to the orientation of an orbital in space.
State the values of $m$ for the orbital which contains the tenth electron.
3. Iron can form a variety of complexes with different ligands. Each complex has different properties.
(a) Some iron complex ions are paramagnetic. Paramagnetic substances are substances that are weakly attracted by a magnetic field.

Paramagnetism is caused by the presence of unpaired electrons.
In both $\left[\mathrm{Fe}\left(\mathrm{H}_{2} \mathrm{O}\right)_{6}\right]^{2+}$ and $\left[\mathrm{Fe}(\mathrm{CN})_{6}\right]^{4-}$, the $\mathrm{Fe}^{2+}$ ion has six d-electrons, but only $\left[\mathrm{Fe}\left(\mathrm{H}_{2} \mathrm{O}\right)_{6}\right]^{2+}$ is paramagnetic.
(i) Complete the d-orbital box diagram for the complex ion $\left[\mathrm{Fe}(\mathrm{CN})_{6}\right]^{4-}$.

(An additional diagram, if required, can be found on Page 28)
(ii) The relative ability of a ligand to split the d-orbitals when forming a complex ion is given by the spectrochemical series.
The spectrochemical series for some ligands is shown below.

$$
\mathrm{CN}^{-}>\mathrm{NH}_{3}>\mathrm{H}_{2} \mathrm{O}
$$

The $\left[\mathrm{Fe}\left(\mathrm{H}_{2} \mathrm{O}\right)_{6}\right]^{2+}$ ion has unpaired electrons and is therefore paramagnetic.
Explain how unpaired electrons can arise in this complex ion.
(iii) Explain why all of the complex ions formed by the $\mathrm{Fe}^{3+}$ ion are paramagnetic.
3. (continued)
(b) Human blood is red due to the presence of haemoglobin bonded to oxygen. Other animals have different coloured blood due to the presence of different complex ions bonded to oxygen.
Coror of blood
(i) State the co-ordination number of the $\mathrm{Fe}^{2+}$ ion in haemoglobin.
3. (b) (continued)
(ii) Spiders' blood contains the oxyhaemocyanin complex ion. Oxyhaemocyanin contains copper ions.

Suggest an analytical technique that could be used to determine the presence of copper ions in spiders' blood.
(iii) Using your knowledge of chemistry, comment on why these animals have different coloured blood.
4. As part of an Advanced Higher Chemistry project, a student determined the chloride ion concentration of seawater by two different methods.

## Volumetric method

A sample of seawater was titrated with standard silver nitrate solution.

## Gravimetric method

A sample of seawater was reacted with standard silver nitrate solution to form a precipitate. The precipitate was collected by filtration and weighed.
(a) For the volumetric method, a $0.1 \mathrm{moll}^{-1}$ standard solution of silver nitrate was prepared by following the instructions below.

1. Dry 5 g of silver nitrate for 2 hours at $100^{\circ} \mathrm{C}$ and allow to cool.
2. Weigh accurately approximately $4 \cdot 25 \mathrm{~g}$ of solid silver nitrate.
3. Use this sample to prepare $250 \mathrm{~cm}^{3}$ of standard silver nitrate solution.
(i) State what is meant by "weigh accurately approximately" $4 \cdot 25 \mathrm{~g}$ of solid silver nitrate.
(ii) Outline how the student would have prepared the standard silver nitrate solution.
(iii) Samples of the diluted seawater were titrated and the average titre was found to be $3.9 \mathrm{~cm}^{3}$.

Suggest an improvement the student could make to reduce the uncertainty in the titre value.
4. (continued)
(b) For the gravimetric method, standard silver nitrate solution was added to a seawater sample to form a precipitate of silver chloride.
(i) Describe how the filtration should have been carried out to ensure a fast means of separating the precipitate from the reaction mixture.
(ii) After the precipitate was filtered, the filtrate was tested with a few drops of silver nitrate solution.
Suggest why the student tested the filtrate in this way.
(c) The student also planned to carry out an analysis of chloride ion concentration in fresh river water.

Explain why the volumetric method, rather than the gravimetric method, would be more appropriate for the analysis of chloride ion concentration in fresh river water.
5. Mandelic acid, 2-hydroxy-2-phenylethanoic acid, is a component of skin care products.

mandelic acid
(a) Mandelic acid is a weak acid.
$\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{CH}(\mathrm{OH}) \mathrm{COOH}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \rightleftharpoons \mathrm{C}_{6} \mathrm{H}_{5} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}^{-}(\mathrm{aq})+\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})$
Write the expression for the dissociation constant, $K_{\mathrm{a}}$, for mandelic acid.
(b) A $100 \mathrm{~cm}^{3}$ sample of skin care product contained 10.0 g of mandelic acid. The $K_{\mathrm{a}}$ of mandelic acid is $1.78 \times 10^{-4}$.
(i) Calculate the concentration of the mandelic acid, in $\mathrm{moll}^{-1}$, present in the skin care product.
(ii) Using your answer to (b)(i), calculate the pH of a solution of mandelic acid of this concentration.
6. Chlorine is a versatile element which forms a wide range of compounds.
(a) One example of a compound containing chlorine is vanadium(IV) chloride. It reacts vigorously with water forming a blue solution.

The blue solution absorbs light of wavelength 610 nm .
Calculate the energy, in $\mathrm{kJ} \mathrm{mol}^{-1}$, associated with this wavelength.
(b) Chlorine dioxide, $\mathrm{ClO}_{2}$, is used in water sterilisation.

An experiment was carried out to determine the kinetics for the reaction between chlorine dioxide and hydroxide ions.
$2 \mathrm{ClO}_{2}(\mathrm{aq})+2 \mathrm{OH}^{-}(\mathrm{aq}) \rightarrow \mathrm{ClO}_{2}^{-}(\mathrm{aq})+\mathrm{ClO}_{3}^{-}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell)$
Under certain conditions the following results were obtained.

| $\left[\mathrm{ClO}_{2}\right]\left(\mathrm{mol} \mathrm{l}^{-1}\right)$ | $\left[\mathrm{OH}^{-}\right]\left(\mathrm{mol} \mathrm{l}^{-1}\right)$ | Initial rate $\left(\mathrm{moll}^{-1} \mathrm{~s}^{-1}\right)$ |
| :---: | :---: | :---: |
| $6.00 \times 10^{-2}$ | $3.00 \times 10^{-2}$ | $2.48 \times 10^{-2}$ |
| $1.20 \times 10^{-1}$ | $3.00 \times 10^{-2}$ | $9.92 \times 10^{-2}$ |
| $1.20 \times 10^{-1}$ | $9.00 \times 10^{-2}$ | $2.98 \times 10^{-1}$ |

(i) Determine the order of reaction with respect to:
(A) $\mathrm{ClO}_{2} \longrightarrow 1$
(B) $\mathrm{OH}^{-}$
6. (b) (continued)
(ii) Write the overall rate equation for the reaction.
(iii) Calculate the value for the rate constant, $k$, including the appropriate units.

7. Aldehydes and ketones can exist in two forms, a keto form and an enol form. For example, the aldehyde ethanal exists in equilibrium with its enol form, ethenol.


These two different molecules are known as tautomers.
(a) State which of the tautomers is the more abundant in this equilibrium.
(b) 3-Methylpentan-2-one is optically active and exists in equilibrium with its enol tautomer.
(i) Circle the chiral centre on 3-methylpentan-2-one.

(ii) Suggest why the optical activity of 3-methylpentan-2-one decreases over time.
7. (b) (continued)
(iii) Draw the skeletal formula for 3-methylpentan-2-one.
(c) A possible mechanism for acid-catalysed enolisation is shown below, where R, R' and R" are alkyl groups.


Using structural formulae and curly arrow notation, show a possible mechanism for the acid-catalysed enolisation of 3-methylpentan-2-one.
8. Aspirin can be used as a starting material for the synthesis of the drug, salbutamol, which is used in the treatment of asthma. Salbutamol acts as an agonist by stimulating receptors in the lungs.
A possible synthetic route is shown.





(a) State what is meant by the term agonist.
(b) Step (1) is known as a Fries rearrangement.

Suggest the role of $\mathrm{AlCl}_{3}$ in this rearrangement.
8. (continued)
(c) Suggest a reaction condition required for Step (3).
(d) Identify the type of reaction taking place in Step (4).
(e) Step (5) involves several reactions.

Suggest a suitable reagent that could be used to convert the ketone carbonyl group to the hydroxyl group.
8. (continued)
(f) The purity of salbutamol can be determined using a variety of analytical techniques.

Using your knowledge of chemistry, discuss how analytical techniques could be used to determine the purity of salbutamol.
9. Parabens are used as preservatives in cosmetics, pharmaceutical products and foods. Parabens are esters of 4-hydroxybenzoic acid.

One common paraben used as a food preservative is ethylparaben.

(a) Ethylparaben is an aromatic compound containing both sigma and pi bonds.
(i) Write the molecular formula for ethylparaben.
(ii) State the type of hybridisation which is adopted by the carbon atoms in the aromatic ring.
(iii) Describe how pi bonds form.
9. (continued)
(b) Another preservative is sodium 4-hydroxybenzoate. It can be prepared by refluxing ethylparaben with sodium hydroxide solution.

(i) Complete the diagram below to show how the reaction mixture is heated under reflux.


Heating mantle
(An additional diagram, if required, can be found on Page 28)
(ii) At the start of the reaction, two layers were observed in the reaction mixture.
Explain why only one layer was observed when the reaction was complete.
9. (b) (continued)
(iii) Explain fully why a solution of the salt sodium 4-hydroxybenzoate has a pH greater than 7 .
(iv) After refluxing, dilute hydrochloric acid was added to the reaction mixture and a white precipitate of 4-hydroxybenzoic acid was produced. The crude 4-hydroxybenzoic acid was recrystallised.
4-hydroxybenzoic acid is soluble in different solvents but only some of these solvents are suitable for recrystallisation.
State two factors that should be considered when selecting an appropriate solvent for this recrystallisation.
(v) In this experiment, the percentage yield of 4-hydroxybenzoic acid was $77 \cdot 5 \%$.
Calculate the mass of ethylparaben ( $\mathrm{GFM}=166 \mathrm{~g}$ ) required to produce $2 \cdot 48 \mathrm{~g}$ of 4-hydroxybenzoic acid (GFM = 138 g ).
10. Phenylbutazone is an anti-inflammatory drug used for the short-term treatment of pain and fever in animals.
(a) Phenylbutazone can be synthesised, in a multi-step process, starting from compound $A$.

Elemental microanalysis showed that compound A has a composition, by mass, of
$50 \cdot 0 \% \mathrm{C} ; \quad 5 \cdot 60 \% \mathrm{H} ; \quad 44 \cdot 4 \% \mathrm{O}$

Calculate the empirical formula of compound A.
(b) An infra-red spectrum for compound A is shown below.


Identify the functional group responsible for the peak at $1710 \mathrm{~cm}^{-1}$.
10. (continued)
(c) The mass spectrum for compound A is shown below.

(i) Write the molecular formula for compound A.
(ii) Suggest a possible ion fragment that may be responsible for the peak at m/z 27.
(d) Considering all the evidence, draw a structural formula for compound A. 1

## 2016 Chemistry

## Advanced Higher

## Finalised Marking Instructions

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Detailed Marking Instructions for each question

## Section 1

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

## Section 2

| Question |  |  | Expected response |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | (a) | (i) | $-44 \mathrm{~kJ} \mathrm{~mol}^{-1}$ |  | 1 | -40 also acceptable. <br> Units not needed but must be correct if given. |
|  |  | (ii) | $-130 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~mol}^{-1}$ <br> OR $\begin{aligned} \Delta \mathrm{G}^{\circ} & =\Sigma \mathrm{G}^{\circ} \text { products }-\Sigma \mathrm{G}^{\circ} \text { reactants } \\ & =-175-(68-237) \\ & =-6(\mathrm{~kJ} \mathrm{~mol} \end{aligned}$ $\Delta S^{\circ}=\left(\Delta H^{\circ}-\Delta G^{\circ}\right) / T$ <br> (or use of $\Delta \mathrm{G}^{\circ}=\Delta \mathrm{H}^{\circ}-\mathrm{T} \Delta \mathrm{S}^{\circ}$ ) $\begin{aligned} & =(-44-(-6)) / 298 \\ & =-0 \cdot 128 \mathrm{~kJ} \mathrm{~K}^{-1} \mathrm{~mol}^{-1} \\ & =-130 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~mol}^{-1} \end{aligned}$ | (3) <br> (1) <br> (1) <br> (1) | 3 | $-100 /-128 /-127 \cdot 5 \text { also }$ acceptable. <br> Units not needed for final answer but must be correct if given. <br> Follow through applies. |
|  | (b) |  | $340 \mathrm{~K}$ <br> OR <br> Reaction becomes feasible when $\Delta \mathrm{G}=0$ <br> Therefore $\mathrm{T}=\Delta \mathrm{H} / \Delta \mathrm{S}$ $\begin{aligned} & \mathrm{T}=44 / 0 \cdot 130 \\ & \mathrm{~T}=340 \mathrm{~K} \end{aligned}$ | (2) <br> (1) <br> (1) | 2 | 300/338/338.5 are also acceptable. <br> Follow through applies, from a(i) and/or a(ii). <br> Units not needed for final answer but must be correct if given. |
| 2. | (a) |  | $1 s^{2} 2 s^{2} 2 p^{6}$ |  | 1 | If orbital boxes are given they must be correct and the correct notation is also required. |
|  | (b) |  |  |  | 1 | Any orientation of this shape allowed. <br> If axes are drawn, then a lobe of the orbital must lie on an axis. |
|  | (c) |  | -1, 0, (+)1 |  | 1 |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3. | (a) | (i) |  | 1 | Full headed arrows are acceptable, but spin must be shown. |
|  |  | (ii) | 1 mark is awarded for recognising that there is a small energy gap. <br> 1 mark is awarded for recognising that electrons are promoted. | 2 | Less energy is required to promote an electron <br> OR <br> $\Delta$ is small/less (than for $\mathrm{CN}^{-}$) <br> OR <br> Energy difference between levels is less <br> Electrons can occupy all of the d-orbitals <br> OR <br> Electrons can occupy the higher energy d-orbitals <br> OR <br> Electrons can be promoted between energy levels. |

Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :---: | :--- |
| (iii) | $\mathrm{Fe}^{3+}$ has five/odd number of (d-)electrons <br> OR <br> It is 3d ${ }^{5}$ <br> OR <br> It has a half-filled d-subshell <br> OR <br> It has a half-filled d-orbital. | 1 | A mark should not be <br> awarded for "It has an <br> unpaired electron". |  |
| (b) | (i) | 4/four. <br> (ii) | Flame test <br> OR <br> Atomic absorption <br> OR <br> Atomic emission. | 1 |


| Question |  | Expected response | Max <br> mark | Additional guidance |
| :---: | :---: | :--- | :---: | :---: |
| (iii) | This is an open ended question <br> 1 mark: The student has demonstrated, at <br> an appropriate level, a limited <br> understanding of the chemistry involved. <br> The student has made some statement(s) <br> which is/are relevant to the situation, <br> showing that at least a little of the <br> chemistry within the problem is understood. | $\mathbf{3}$ | Zero marks should be <br> awarded if: <br> The student has <br> demonstrated no <br> understanding of the <br> chemistry involved at an <br> appropriate level. There is <br> no evidence that the <br> student has recognised the <br> area of chemistry involved <br> or has given any statement <br> of a relevant chemistry <br> principle. This mark would <br> aso be given when the <br> student merely restates <br> the chemistry given in the <br> question. |  |
| 2 marks: The student has demonstrated, at <br> an appropriate level, a reasonable <br> understanding of the chemistry involved. <br> The student makes some statement(s) which <br> is/are relevant to the situation, showing <br> that the problem is understood. | 3 marks: The maximum available mark <br> would be awarded to a student who has <br> demonstrated, at an appropriate level, a <br> good understanding, of the chemistry <br> involved. The student shows a good <br> comprehension of the chemistry of the <br> situation and has provided a logically <br> correct answer to the question posed. This <br> type of response might include a statement <br> of the principles involved, a relationship or <br> an equation, and the application of these to <br> respond to the problem. This does not <br> mean the answer has to be what might be <br> termed an "excellent" answer or a <br> "complete" one. |  |  |  |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (a) | (i) | The exact mass should be known/measured and should be close to 4.25 g OR <br> The mass should be around $4 \cdot 25 \mathrm{~g}$ but with an accurate reading. | 1 |  |
|  |  | (ii) | Dissolve/make a solution of the silver nitrate in distilled/deionised water (in a beaker). <br> Transfer the solution/it and the rinsings (to the standard/volumetric flask) <br> Make (the solution) up to the mark in a standard/volumetric flask (with distilled/deionised water). | 2 | The first mark should not be awarded if the solid is washed directly into the flask. <br> Only one mention of distilled/deionised water is required. <br> Only one mention of standard/volumetric flask is required. |
|  |  | (iii) | Titrate a larger sample (of the seawater) OR <br> Dilute the standard silver nitrate solution OR <br> Prepare or use a lower concentration of silver nitrate solution <br> OR <br> Dilute the seawater less <br> OR <br> Use a micro-burette <br> OR <br> Use class A glassware. | 1 | A general statement such as "use more accurate apparatus" should not be awarded this mark. |


| Question |  | Expected response |  | Max <br> mark |
| :--- | :--- | :--- | :---: | :--- |
| (i) | Additional guidance <br> Vacuum filtration <br> OR <br> Acceptable diagram <br> OR <br> Filtration under suction <br> OR <br> Fluted filter paper. | $\mathbf{1}$ | A mark should not be <br> awarded for "use a <br> Buchner funnel/flask" <br> without further <br> explanation. |  |
| (ii) | To check the reaction is complete <br> OR <br> To check all chloride ions have reacted <br> OR <br> To check that no more precipitate is formed <br> OR <br> If there is a precipitate the reaction is not <br> complete. | $\mathbf{1}$ | A mark should not be <br> awarded for "to see if <br> there is excess reactant" <br> on its own. <br> An answer that refers only <br> to chlorine should be <br> awarded zero marks. |  |
| (c) | Titration can be used with lower chloride <br> concentrations <br> OR <br> Gravimetric method would produce too <br> little/no precipitate. | $\mathbf{1}$ | If an answer refers to <br> chlorine this should be <br> ignored. |  |


| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5. | (a) |  | $K_{a}=\frac{\left[\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}^{-}\right]\left[\mathrm{H}_{3} \mathrm{O}^{+}\right]}{\left[\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{CH}(\mathrm{OH}) \mathrm{COOH}\right]}$ | 1 | Award mark for K without subscript a. <br> [ $\mathrm{H}_{2} \mathrm{O}$ ] should not be included. <br> If state symbols are included they must be correct but do not need brackets. <br> All square brackets and charges must be included. |
|  | (b) | (i) | $\begin{equation*} 0.658 \mathrm{~mol} \mathrm{l}^{-1} \tag{2} \end{equation*}$ <br> OR moles of mandelic acid $\begin{equation*} 10 \mathrm{~g} / 152 \mathrm{~g}=0.0658 \tag{1} \end{equation*}$ concentration of mandelic acid $\begin{equation*} 0.0658 / 0 \cdot 100=0.658 \tag{1} \end{equation*}$ | 2 | $0.66 / 0 \cdot 6579 / 0.65789$ are also acceptable. <br> Units not needed for final answer but must be correct if given. |
|  |  | (ii) | $\begin{equation*} 1 \cdot 97 \tag{3} \end{equation*}$ <br> OR $\begin{align*} \mathrm{pH} & =1 / 2 \mathrm{pK}_{\mathrm{a}}-1 / 2 \log \mathrm{c}  \tag{1}\\ \mathrm{pK}_{\mathrm{a}} & \left(-\operatorname{logh}_{\mathrm{a}}=3.75\right)  \tag{1}\\ \mathrm{pH} & =1.875-(-0.0909) \\ & =1.97 \tag{1} \end{align*}$ <br> OR $\begin{align*} {\left[\mathrm{H}^{+}\right] } & =\int\left(\mathrm{K}_{\mathrm{a}} \mathrm{c}\right)  \tag{1}\\ {\left[\mathrm{H}^{+}\right] } & =\int\left(1.78 \times 10^{-4} \times 0.658\right) \\ & =0.0108  \tag{1}\\ \mathrm{pH} & =1.97 \tag{1} \end{align*}$ | 3 | 2.0/1.966/1.9659 are also acceptable. <br> The mark is not awarded for a final answer of pH 2 (too few significant figures). <br> Allow follow through. <br> If incorrect equation is used, then maximum one mark can be awarded for use of the correct pKa value. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (a) |  | $196 \mathrm{~kJ} \mathrm{~mol}^{-1}$ <br> OR $\begin{equation*} E=\frac{L h c}{\lambda} \tag{1} \end{equation*}$ <br> OR $\begin{align*} & =\frac{6 \cdot 02 \times 10^{23} \times 6 \cdot 63 \times 10^{-34} \times 3.00 \times 10^{8}}{610 \times 10^{-9}} \\ & =1.96 \times 10^{5} \\ & =196 \mathrm{~kJ} \mathrm{~mol}^{-1} \tag{1} \end{align*}$ | 2 | 200/196•3/196.29 are also acceptable. <br> Units not needed for final answer but must be correct if given. |
|  | (b) | (i) <br> (A) | $2^{\text {nd }}$ order/2/[ $\left.\mathrm{ClO}_{2}\right]^{2}$ | 1 |  |
|  |  | (i) <br> (B) | $1^{\text {st }}$ order/1/[ $\left.\mathrm{OH}^{-}\right]^{1}$ | 1 | Mark not awarded for [ $\mathrm{OH}^{-}$] |
|  |  | (ii) | Rate $=\mathrm{k}\left[\mathrm{ClO}_{2}\right]^{2}\left[\mathrm{OH}^{-}\right]$ | 1 | Follow through allowed. <br> Mark not awarded for capital K. |
|  |  | (iii) | $\begin{equation*} 230 \mathrm{l}^{2} \mathrm{~mol}^{-2} \mathrm{~s}^{-1} \tag{2} \end{equation*}$ <br> OR $\begin{align*} & k=\frac{2 \cdot 48 \times 10^{-2}}{\left[6 \cdot 00 \times 10^{-2}\right]^{2} \times\left[3 \cdot 00 \times 10^{-2}\right]} \\ & =230 \tag{1} \end{align*}$ <br> OR $\begin{equation*} \mathrm{l}^{2} \mathrm{~mol}^{-2} \mathrm{~s}^{-1} \tag{1} \end{equation*}$ | 2 | 200/229.6/229.63 are also acceptable. <br> Any order of correct units is acceptable <br> Follow through applies. <br> Units and value must be consistent with answer from b (ii). |

Go to Topic Grid

| Question |  |  | Expected response |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (a) |  | Ethanal/the keto form/left hand side/ reactant. |  | 1 |  |
|  | (b) | (i) |  |  | 1 |  |
|  |  | (ii) | A racemic mixture is forming <br> OR <br> (When the enol form converts to the keto) the other enantiomer/optical isomer can be formed. |  | 1 | Mark not awarded if molecules described as tautomers. |
|  |  | (iii) |  |  | 1 | Any orientation is accepted. |
|  | (c) |  |      <br> Mechanism following example given in question. |     <br> Correct alternative mechanism. | 3 | 1 for product. <br> 1 for the intermediate positive charge must be shown. <br> 1 for the curly arrows - all 3 must be correct and whole headed arrows must be used. <br> $\mathrm{C}_{2} \mathrm{H}_{5}$ is acceptable and can be drawn in any position. <br> If bond is drawn to wrong part of the alkyl group in the intermediate or product, then mark is not awarded. This would only be done once per question. |

Go to Topic Grid

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 8. | (a) | An agonist is a molecule which behaves like/mimics/enhances/triggers the natural response (of the body) <br> OR <br> An agonist produces a response similar to the (body's) natural active compound. | 1 | Do not accept a response which only restates the question stem eg "stimulates receptors". |
|  | (b) | Catalyst. | 1 | Ignore references to homogeneous and heterogeneous. |
|  | (c) | UV (Light). | 1 | Light on its own is not acceptable. |
|  | (d) | (Nucleophilic) substitution. | 1 | $\mathrm{S}_{\mathrm{N}} 1$ or $\mathrm{S}_{\mathrm{N}} 2$ would be acceptable. <br> Mark is not awarded for electrophilic substitution. |
|  | (e) | $\mathrm{LiAlH}_{4}$ or lithium aluminium hydride or Lithal <br> OR <br> $\mathrm{NaBH}_{4}$ or sodium borohydride. | 1 | Mark is not awarded for LAH. |


| Question |  | Expected response | Max <br> mark | Additional guidance |
| :---: | :---: | :--- | :---: | :---: |
| (f) | This is an open ended question <br> 1 mark: The student has demonstrated, at <br> an appropriate level, a limited <br> understanding of the chemistry involved. <br> The student has made some statement(s) <br> which is/are relevant to the situation, <br> showing that at least a little of the <br> chemistry within the problem is understood. <br> 2 marks: The student has demonstrated, at <br> an appropriate level, a reasonable <br> understanding of the chemistry involved. <br> The student makes some statement(s) which <br> is/are relevant to the situation, showing <br> that the problem is understood. | $\mathbf{3}$ | Zero marks should be <br> awarded if: <br> The student has <br> demonstrated no <br> understanding of the <br> chemistry involved at an <br> appropriate level. There is <br> no evidence that the <br> student has recognised the <br> area of chemistry involved <br> or has given any statement <br> of a relevant chemistry <br> principle. This mark would <br> also be given when the <br> student merely restates <br> the chemistry given in the <br> question. |  |
| 3 marks: The maximum available mark <br> would be awarded to a student who has <br> demonstrated, at an appropriate level, a <br> good understanding, of the chemistry <br> involved. The student shows a good <br> comprehension of the chemistry of the <br> situation and has provided a logically <br> correct answer to the question posed. This <br> type of response might include a statement <br> of the principles involved, a relationship or <br> an equation, and the application of these to <br> respond to the problem. This does not <br> mean the answer has to be what might be <br> termed an "excellent" answer or a <br> "complete" one. | ( |  |  |  |

Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |  |
| :--- | :--- | :--- | :--- | :---: | :--- |
| 9. | (a) | (i) | $\mathrm{C}_{9} \mathrm{H}_{10} \mathrm{O}_{3}$ | $\mathbf{1}$ | Any order is acceptable. |
|  |  | (ii) | $\mathrm{sp}^{2}$ | $\mathbf{1}$ | The "2" must follow "sp". |
| (iii) | Orbitals overlap sideways <br> OR <br> Orbitals bond side-on <br> OR <br> A suitable diagram. | $\mathbf{1}$ | No mark is awarded if any <br> mention or drawing of s <br> orbitals <br> No mark is awarded for an <br> answer that refers to <br> molecular orbitals <br> overlapping. |  |  |
| (b) | (i) | Suitable diagram showing a workable <br> method of condensing the vapour back into <br> the reaction vessel. | $\mathbf{1}$ | Diagram should <br> - be cross-sectional with <br> inner wall shown <br> - be an open system <br> - be sealed around the <br> flask neck <br> - have water going in at <br> bottom and out at top. |  |
|  | (ii) | The (named) product/products are soluble/ <br> miscible/have dissolved <br> OR <br> There are no reactants left <br> OR <br> There is only product left. | $\mathbf{1}$ | A mark should not be <br> awarded for <br> "The products are miscible <br> with/soluble in each <br> other" without further <br> explanation. |  |



Go to Topic Grid

| Question | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: |
| (v) | $\begin{equation*} 3.85 \mathrm{~g} \tag{2} \end{equation*}$ <br> OR $\begin{align*} & 77 \cdot 5 \%=2 \cdot 48 \\ & 100 \%=\frac{2 \cdot 48}{0 \cdot 775}=3 \cdot 20 \tag{1} \end{align*}$ <br> THEN: <br> 1 mole 4-hydroxybenzoic acid $=138 \mathrm{~g}$ $3.20 \mathrm{~g}=\frac{3.20}{138}=0.0232 \text { moles }$ <br> 1 mole 4-hydroxybenzoic acid is produced from 1 mole ethylparaben. <br> 0.0232 moles ethylparaben required <br> 1 mole ethylparaben $=166 \mathrm{~g}$ <br> 0.0232 moles $=0.0232 \times 166$ $\begin{equation*} =3.85 \mathrm{~g} \tag{1} \end{equation*}$ <br> OR THEN: $\begin{array}{\|cl} \text { 4-hydroxybenzoic acid } & : \\ 1 \text { mole } & : \begin{array}{c} 1 \text { mole } \\ 138 \mathrm{~g} \end{array} \\ 3.20 \mathrm{~g} & : \frac{3.20 \times 166}{138} \\ & =3.85 \mathrm{~g} \end{array}$ <br> OR $\begin{align*} & 2.48 / 138=0.01797 \\ & 0.01797 \times 166 \\ & =2.9832  \tag{1}\\ & 2.9832 / 0.775 \\ & =3.85 \mathrm{~g} \tag{1} \end{align*}$ | 2 | $3.9 \mathrm{~g} / 3.849 \mathrm{~g} / 3.8493 \mathrm{~g}$ are also acceptable. <br> Correct unit, g or grams, is required for the second mark. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10. | (a) |  | $\mathrm{C}_{3} \mathrm{H}_{4} \mathrm{O}_{2}$ <br> OR <br> C $50 \cdot 0 / 12: 4 \cdot 167$ <br> H 5.60/1 : 5.60 <br> O 44.4/16:2.78 $\begin{equation*} \mathrm{C}_{3} \mathrm{H}_{4} \mathrm{O}_{2} \tag{1} \end{equation*}$ | 2 | Any order is acceptable. <br> 1 mark for correct numbers of moles. <br> 1 mark for a correct formula from calculated number of moles. |
|  | (b) |  | $\mathrm{C}=\mathrm{O}$ (stretch) <br> OR <br> Carbonyl <br> OR <br> $\mathrm{C}=0$ (stretch) carboxyl / carboxylic acid. | 1 | A mark should not be awarded for carboxyl or carboxylic acid by itself. |
|  | (c) | (i) | $\mathrm{C}_{3} \mathrm{H}_{4} \mathrm{O}_{2}$ | 1 | Any order is acceptable. |
|  |  | (ii) | $\left[\mathrm{C}_{2} \mathrm{H}_{3}\right]^{+}$ <br> OR <br> ${ }^{+} \mathrm{C}_{2} \mathrm{H}_{3}$ <br> OR $\left[\mathrm{CH}_{2} \mathrm{CH}\right]^{+}$ <br> OR <br> Correct full structural formula of above. | 1 | The positive charge must be shown and not placed on a hydrogen atom eg not $\mathrm{C}_{2} \mathrm{H}_{3}{ }^{+}$ <br> A mark is not awarded for $\left[\mathrm{CH}_{3} \mathrm{C}\right]^{+}$ |
|  | (d) |  |  | 1 | Correct full structural, shortened structural or skeletal formulae can all be accepted. <br> Allow correct follow though from ALL evidence that the candidate has written for parts (a), (b) and (c) of the question. |

[END OF MARKING INSTRUCTIONS]

MONDAY, 8 MAY
9:00 AM - 11:30 AM

Instructions for the completion of Section 1 are given on Page 02 of your question and answer booklet X713/77/01.

Record your answers on the answer grid on Page 03 of your question and answer booklet.
You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## SECTION 1 - 30 marks

## Attempt ALL questions

1. All noble gases are characterised by the completion of the outermost orbital.

This orbital is
A an s-orbital
B a p-orbital
C a d-orbital
D an s or p-orbital.
2. The electronic configuration of an atom of $X$, in its ground state, is $1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{6} 3 d^{1} 4 s^{2}$. $X$ is an atom of

A calcium
B scandium
C titanium
D vanadium.
3. Which line in the table could represent the four quantum numbers of an outer electron in an $\mathrm{Mg}^{2+}$ ion?

|  | $n$ | $l$ | $m$ | $s$ |
| :---: | :---: | :---: | :---: | :---: |
| A | 2 | 1 | -2 | $-1 / 2$ |
| B | 2 | 0 | 0 | $+1 / 2$ |
| C | 2 | 1 | -1 | $+1 / 2$ |
| D | 3 | 0 | 0 | $-1 / 2$ |

4. The coordination number of an ionic lattice can be determined by using the following equation.

$$
\text { radius ratio }=\frac{\text { radius of positive ion }}{\text { radius of negative ion }}
$$

| Radius ratio | Coordination number |
| :--- | :---: |
| less than 0.23 | 3 |
| $0.23-0.42$ | 4 |
| $0.42-0.73$ | 6 |
| greater than 0.73 | 8 |

What is the coordination number in zinc(II) sulfide?
A 3
B 4
C 6
D 8
5. What is the formula for the diaquatetrachlorocobaltate(II) ion?

A $\left[\mathrm{CoCl}_{4}\left(\mathrm{H}_{2} \mathrm{O}\right)_{2}\right]^{2-}$
B $\left[\mathrm{CoCl}_{2}\left(\mathrm{H}_{2} \mathrm{O}\right)_{4}\right]^{2-}$
C $\left[\mathrm{CoCl}_{4}\left(\mathrm{H}_{2} \mathrm{O}\right)_{2}\right]^{2+}$
D $\left[\mathrm{CoCl}_{2}\left(\mathrm{H}_{2} \mathrm{O}\right)_{4}\right]^{2+}$
6. Which of the following indicators is most suitable to use in a titration of dilute hydrochloric acid solution with dilute ammonia solution?

A Bromothymol blue
B Phenolphthalein
C Methyl orange
D Phenol red
7. The pH of a solution of benzoic acid with concentration $0.01 \mathrm{moll}^{-1}$ is

A 1.1
B 2.0
C 3.1
D $5 \cdot 2$.
8. A reaction must be exothermic if

A both $\Delta G^{\circ}$ and $\Delta S^{\circ}$ are negative
B both $\Delta G^{\circ}$ and $\Delta S^{\circ}$ are positive
C $\Delta G^{\circ}$ is negative
D $\Delta S^{\circ}$ is positive.
9. For the reaction
$A+B \rightarrow C$
the following data were obtained.

| Experiment | Initial concentration <br> of $A\left(\mathrm{moll}^{-1}\right)$ | Initial concentration <br> of $B\left(\mathrm{moll}^{-1}\right)$ | Initial rate of formation <br> of $C\left(\mathrm{~mol} \mathrm{l}^{-1} \mathrm{~s}^{-1}\right)$ |
| :---: | :---: | :---: | :---: |
| 1 | 0.1 | 0.1 | 0.05 |
| 2 | 0.2 | 0.1 | 0.05 |
| 3 | 0.1 | 0.2 | X |

Given that the rate equation is
Rate $=k[B]^{2}$
the value of $X$ will be
A 0.05
B $\quad 0.10$
C $\quad 0.15$
D 0.20 .
10. The rate equation for the reaction between nitrogen monoxide and chlorine is rate $=k\left[\mathrm{NO}^{2}\left[\mathrm{Cl}_{2}\right]\right.$

The units for the rate constant, k , in this reaction are
A $\mathrm{s}^{-1}$
B $\mathrm{moll}^{-1} \mathrm{~s}^{-1}$
C $\quad \mathrm{mol}^{-1} \mathrm{~s}^{-1}$
D $\quad l^{2} \mathrm{~mol}^{-2} \mathrm{~s}^{-1}$.
11. Which of the following describes the bonding in ethane?

A $\mathrm{sp}^{2}$ hybridisation with sigma bonds only.
B $\mathrm{sp}^{3}$ hybridisation with sigma bonds only.
C $\mathrm{sp}^{2}$ hybridisation with sigma and pi bonds.
D $\mathrm{sp}^{3}$ hybridisation with sigma and pi bonds.
12. Pyridine has the following structure.


The number of sigma bonds in a molecule of pyridine is
A 3
B 6
C 11
D 12 .
13. A racemic mixture is defined as

A a mixture of two enantiomers
B a pair of enantiomers mixed in equal proportions
C a mixture of two geometric isomers
D a pair of geometric isomers mixed in equal proportions.
14. $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{Br}+\mathrm{NH}_{3} \rightarrow \mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{NH}_{2}+\mathrm{HBr}$


The nucleophiles in these two reactions are
A $\mathrm{CH}_{3} \mathrm{Br}$ and $\mathrm{NH}_{3}$
B $\mathrm{OH}^{-}$and $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{Br}$
C $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{Br}$ and $\mathrm{CH}_{3} \mathrm{Br}$
D $\mathrm{NH}_{3}$ and $\mathrm{OH}^{-}$.
15. A compound X has a $G F M$ of less than 100 g .

Complete combustion of compound X produces carbon dioxide and water only.
Reduction of compound X produces a secondary alcohol.
Compound X is most likely to be

A


B


C


D

16.

| Amine | Boiling point $\left({ }^{\circ} \mathrm{C}\right)$ |
| :---: | :---: |
| $\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{~N}\left(\mathrm{CH}_{3}\right)_{2}$ | 37.5 |
| $\left(\mathrm{C}_{2} \mathrm{H}_{5}\right)_{2} \mathrm{NH}$ | $56 \cdot 3$ |
| $\mathrm{C}_{4} \mathrm{H}_{9} \mathrm{NH}_{2}$ | 77.8 |

Based on the information in the table,
A the tertiary amine has the highest boiling point
B the secondary amine has the lowest boiling point
C the primary amine has a lower boiling point than the tertiary amine
D the secondary amine has a lower boiling point than the primary amine.
17. Compound $Y$ reacts with the product of its own oxidation to form an ester.

Compound $Y$ could be
A propanal
B propan-1-ol
C propan-2-ol
D propanoic acid.
18. Which of the following statements about benzene is correct?

A The benzene molecule is planar.
B Benzene does not react with electrophiles.
C Benzene readily undergoes nucleophilic attack.
D The benzene molecule contains carbon to carbon bonds of two different lengths.
19. Chlorine has two isotopes, ${ }^{35} \mathrm{Cl}$ and ${ }^{37} \mathrm{Cl}$.

These isotopes are present in a sample of 1,1,1-trichloroethane, $\mathrm{C}_{2} \mathrm{H}_{3} \mathrm{Cl}_{3}$. The number of molecular ion peaks expected in the mass spectrum of $1,1,1$-trichloroethane is

A 6
B 4
C 3
D 2 .
20. The following substance was analysed using an infrared spectrometer.


The spectrum produced would not have a significant peak in the wave number range
A $\quad 1700-1680 \mathrm{~cm}^{-1}$
B $\quad 2962-2853 \mathrm{~cm}^{-1}$
C $\quad 3100-3000 \mathrm{~cm}^{-1}$
D $\quad 3500-3300 \mathrm{~cm}^{-1}$.
21. Antisense drugs are a group of medicines that act by binding to DNA to block the synthesis of some proteins.

Which line in the table is correct for antisense drugs?

|  | Classification | Receptor |
| :---: | :---: | :---: |
| A | antagonist | DNA |
| B | antagonist | protein |
| C | agonist | DNA |
| D | agonist | protein |

22. Which of the following would be most suitable as a reagent in the gravimetric analysis of silver ions?

A Sodium nitrate
B Potassium sulfate
C Barium carbonate
D Ammonium chloride
23. Using colorimetry, the most appropriate filter for determining the concentration of green nickel ions, $\mathrm{Ni}^{2+}(\mathrm{aq})$, in a solution, would be

A 390 nm
B 490 nm
C 540 nm
D 680 nm .
24. The diagram shows a thin layer chromatogram for a mixture of amino acids.


Which amino acid has an $R_{f}$ value of approximately $0 \cdot 75$ ?
A Amino acid S
B Amino acid R
C Amino acid Q
D Amino acid P
25. Which line in the table shows the properties of the most suitable solvent to extract caffeine from an aqueous solution of tea?

| A | Caffeine is more soluble in the <br> solvent than it is in the tea solution. | The solvent is immiscible in the tea <br> solution. |
| :---: | :--- | :--- |
| B | Caffeine is more soluble in the <br> solvent than it is in the tea solution. | The solvent is miscible in the tea <br> solution. |
| C | Caffeine is less soluble in the solvent <br> than it is in the tea solution. | The solvent is miscible in the tea <br> solution. |
| D | Caffeine is less soluble in the solvent <br> than it is in the tea solution. | The solvent is immiscible in the tea <br> solution. |

26. A series of titrations was performed to determine the concentration of vitamin C in a brand of fruit juice. A standard solution of the fruit juice was prepared and titrated with iodine solution.

Which of the following would be a suitable control experiment for this analysis?
A Titrate more samples from the same carton of fruit juice.
B Titrate a solution of pure vitamin C of known concentration.
C Titrate more samples from the standard solution of fruit juice.
D Titrate a sample from a different carton of the same brand of fruit juice.
27. $\mathrm{Ba}(\mathrm{OH})_{2}(\mathrm{aq})+\mathrm{Na}_{2} \mathrm{SO}_{4}(\mathrm{aq}) \rightarrow \mathrm{BaSO}_{4}(\mathrm{~s})+2 \mathrm{NaOH}(\mathrm{aq})$
$50 \mathrm{~cm}^{3}$ of $0.010 \mathrm{moll}^{-1}$ barium hydroxide solution were added to $50 \mathrm{~cm}^{3}$ of $0.010 \mathrm{moll}^{-1}$ sodium sulfate solution.

The concentration of sodium hydroxide, in $\mathrm{moll}^{-1}$, in the resulting solution is
A $\quad 0.0010$
B 0.010
C 0.020
D 0.10 .
28. $1.06 \times 10^{-2}$ moles of phenylamine, $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{NH}_{2}$, react with 5.16 g of bromine. Which equation shows the correct stoichiometry for this reaction?

A $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{NH}_{2}+\mathrm{Br}_{2} \rightarrow \mathrm{C}_{6} \mathrm{H}_{4} \mathrm{BrNH}_{2}+\mathrm{HBr}$
B $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{NH}_{2}+2 \mathrm{Br}_{2} \rightarrow \mathrm{C}_{6} \mathrm{H}_{3} \mathrm{Br}_{2} \mathrm{NH}_{2}+2 \mathrm{HBr}$
C $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{NH}_{2}+3 \mathrm{Br}_{2} \rightarrow \mathrm{C}_{6} \mathrm{H}_{2} \mathrm{Br}_{3} \mathrm{NH}_{2}+3 \mathrm{HBr}$
D $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{NH}_{2}+4 \mathrm{Br}_{2} \rightarrow \mathrm{C}_{6} \mathrm{HBr}_{4} \mathrm{NH}_{2}+4 \mathrm{HBr}$
29. Ibuprofen is used for the relief of pain, fever and inflammation. A structural formula for ibuprofen is shown below.


If one tablet contains 300 mg of ibuprofen, approximately how many tablets can be manufactured from 1 mole of ibuprofen?

A $\quad 6.73 \times 10^{2}$
B $\quad 6.87 \times 10^{2}$
C $6.73 \times 10^{-1}$
D $6.87 \times 10^{-1}$
30. The term accuracy is used to describe how close an experimental result is to the theoretical value. The term precision is used to describe how close a set of duplicate results are to each other.

Four students determined the percentage by mass of chlorine in $\mathrm{BaCl}_{2} .2 \mathrm{H}_{2} \mathrm{O}$.
Which of the following sets of results is both accurate and precise?
A $29.0 \%, 29 \cdot 0 \%, 29 \cdot 1 \%$
B $29 \cdot 1 \%, 28 \cdot 2 \%, 29.9 \%$
C $34 \cdot 0 \%, 34 \cdot 1 \%, 34 \cdot 0 \%$
D $34 \cdot 0 \%, 34 \cdot 3 \%, 33 \cdot 8 \%$
[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

## SECTION 2 - 70 marks

## Attempt ALL questions

1. Many of the paints used by artists contain cadmium compounds.

The presence of cadmium in a paint sample can be detected by atomic emission spectroscopy.
(a) (i) Explain how a line is produced in an emission spectrum.
(ii) Explain why there is a series of lines at discrete wavelengths in the emission spectrum of cadmium.
(b) The cadmium emission spectrum has a line at 644 nm . Calculate the energy, in $\mathrm{kJ} \mathrm{mol}^{-1}$, associated with this wavelength.
2. Phosphorus forms different compounds with chlorine.
(a) When heated, phosphorus pentachloride dissociates to form phosphorus trichloride and chlorine.
$\mathrm{PCl}_{5}(\mathrm{~g}) \rightleftharpoons \mathrm{PCl}_{3}(\mathrm{~g})+\mathrm{Cl}_{2}(\mathrm{~g}) \quad \Delta H=+124 \mathrm{~kJ} \mathrm{~mol}^{-1}$
In an experiment to determine the equilibrium constant, $K, 0 \cdot 100 \mathrm{~mol}$ of $\mathrm{PCl}_{5}$ was placed in a sealed 1.00 litre flask and heated to $250^{\circ} \mathrm{C}$. At equilibrium 0.0420 mol of $\mathrm{PCl}_{3}$ had been formed.
(i) Calculate the equilibrium constant, $K$, for the reaction at $250^{\circ} \mathrm{C}$.
(ii) The temperature of the equilibrium mixture was increased to $400^{\circ} \mathrm{C}$.

Explain the effect of this change in temperature on the value of the equilibrium constant, $K$.
2. (continued)
(b) In the solid state, phosphorus pentachloride is ionic and has the formula $\left[\mathrm{PCl}_{4}\right]^{+}\left[\mathrm{PCl}_{6}\right]^{-}$.
(i) The three-dimensional structure for the $\left[\mathrm{PCl}_{4}\right]^{+}$ion is shown. Complete the table for the $\left[\mathrm{PCl}_{6}\right]^{-}$ion.

| Phosphorus species | Three-dimensional structure |
| :---: | :---: |
| $\left[\mathrm{PCl}_{4}\right]^{+}$ |  |
| $\left[\mathrm{PCl}_{6}\right]^{-}$ |  |

(ii) Phosphorus oxychloride, $\mathrm{POCl}_{3}$, has a similar three-dimensional structure to the $\left[\mathrm{PCl}_{4}\right]^{+}$ion as shown.



Suggest a reason why the bond angle in the $\mathrm{POCl}_{3}$ molecule is less than the bond angle in the $\left[\mathrm{PCl}_{4}\right]^{+}$ion.
3. Zinc is often found in nature together with lead in sulfide ores. Different industrial processes can be used for the production of zinc metal. One of these is an electrolytic process and another is a thermal process.
(a) In the electrolytic process, zinc sulfide is converted into zinc oxide by roasting in a furnace at 1300 K .

$$
2 \mathrm{ZnS}(\mathrm{~s})+3 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{ZnO}(\mathrm{~s})+2 \mathrm{SO}_{2}(\mathrm{~g})
$$

The data in the table refers to this reaction.

| Substance | $\Delta H_{f}^{\circ}\left(\mathrm{kJ} \mathrm{mol}^{-1}\right)$ | $S^{\circ}\left(\mathrm{J} \mathrm{K}^{-1} \mathrm{~mol}^{-1}\right)$ |
| :---: | :---: | :---: |
| $\mathrm{ZnS}(\mathrm{s})$ | -206 | 58 |
| $\mathrm{O}_{2}(\mathrm{~g})$ | 0 | 205 |
| $\mathrm{ZnO}(\mathrm{s})$ | -350 | 44 |
| $\mathrm{SO}_{2}(\mathrm{~g})$ | -297 | 248 |

(i) For the conversion of zinc sulfide into zinc oxide, use the data in the table to calculate:
(A) $\Delta H^{\circ}$, in $\mathrm{kJ} \mathrm{mol}^{-1}$;
(B) $\Delta S^{\circ}$, in $\mathrm{JK}^{-1} \mathrm{~mol}^{-1}$.
(ii) Calculate the theoretical temperature, in K , above which the reaction is no longer feasible.
3. (continued)
(b) In the thermal process, a mixture of zinc oxide and lead oxide is reacted with carbon in a furnace at a temperature of 1200 K .

Data for the metals and metal oxides are shown in the table below.

| Substance | Density <br> $\left(\mathrm{g} \mathrm{cm}^{-3}\right)$ | Melting point <br> $(\mathrm{K})$ | Boiling point <br> $(\mathrm{K})$ |
| :---: | :---: | :---: | :---: |
| Zn | $7 \cdot 1$ | 693 | 1181 |
| Pb | $11 \cdot 3$ | 600 | 2024 |
| ZnO | $5 \cdot 6$ | 2248 | 2633 |
| PbO | $9 \cdot 5$ | 1161 | 1808 |

By considering all the information, suggest how a sample of zinc metal and a sample of lead metal could each be removed from the furnace.
4. Transition metals, such as vanadium and copper, can have variable oxidation states and a wide range of uses.
(a) Vanadium dioxide, $\mathrm{VO}_{2}$, can be used to coat glass.
(i) State the oxidation number of vanadium in $\mathrm{VO}_{2}$.
(ii) Using orbital box notation, write the electronic configuration, in terms of $\mathrm{s}, \mathrm{p}$ and d orbitals, for the vanadium ion in $\mathrm{VO}_{2}$.
(b) Vanadium(III) ions can react with iron(III) ions in solution.

$$
\mathrm{V}^{3+}(\mathrm{aq})+\mathrm{Fe}^{3+}(\mathrm{aq}) \rightarrow \mathrm{V}^{4+}(\mathrm{aq}) \quad+\mathrm{Fe}^{2+}(\mathrm{aq})
$$

(i) The reaction is first order with respect to both $\mathrm{V}^{3+}(\mathrm{aq})$ and $\mathrm{Fe}^{3+}(\mathrm{aq})$. Write the rate equation for this reaction.
4. (b) (continued)
(ii) In the presence of a $\mathrm{Cu}^{2+}(\mathrm{aq})$ catalyst, the reaction mechanism is:

$$
\left.\begin{array}{llll}
\mathrm{Cu}^{2+}(\mathrm{aq}) & +\mathrm{V}^{3+}(\mathrm{aq}) & \stackrel{\text { slow }}{\rightarrow} & \mathrm{Cu}^{+}(\mathrm{aq})
\end{array}+\mathrm{V}^{4+}(\mathrm{aq})\right)
$$

(A) State the order of the reaction with respect to $\mathrm{Fe}^{3+}(\mathrm{aq})$ when a Cu ${ }^{2+}(\mathrm{aq})$ catalyst is present.
Explain your answer.
(B) Explain why $\mathrm{Cu}^{2+}(\mathrm{aq})$ can be described as a homogeneous catalyst in this reaction.
(c) In the Middle Ages, Damascus steel was used for making sword blades.

The steel from a sword blade of mass 1300 g was found to have a vanadium concentration of 71 ppm .
Calculate the total mass of vanadium present in the sword blade.
5. A simple model of an atom is shown.


This simplistic model can be useful to help explain bonding but it is also misleading, as the structure of the atom and bonding are more complicated.

Using your knowledge of chemistry, discuss the strengths and weaknesses of this simple model compared to the concepts of atomic structure and bonding at Advanced Higher level.
6. Wilson's disease is a rare genetic disorder which results in a build-up of copper ions in the body. Unmetabolised copper ions are toxic, leading to health complications.

Copper ions can be removed by reaction with trientine.

trientine
(a) Trientine is a tetradentate ligand that reacts with copper(II) ions in a 1:1 ratio to form a complex ion which can then be removed from the body.
(i) Ligands form dative covalent bonds with metal ions.

State what is meant by a dative covalent bond.
(ii) Draw a structural formula for the complex ion.
6. (continued)
(b) Zinc ethanoate can also be used to treat Wilson's disease.
(i) Zinc ethanoate can be prepared from zinc hydroxide and ethanoic acid.
Name this type of reaction.
(ii) Zinc ethanoate is a salt of a weak acid.

State what is meant by a weak acid.
(iii) A student carried out an experiment to determine the value of $y$ in hydrated zinc ethanoate, $\mathrm{Zn}\left(\mathrm{CH}_{3} \mathrm{COO}\right)_{2} \cdot y \mathrm{y}_{2} \mathrm{O}$. A $5 \cdot 00 \mathrm{~g}$ sample was heated until all the water was removed and a constant mass of $4 \cdot 18 \mathrm{~g}$ was obtained.
(A) Name the piece of apparatus that should be used to store the zinc ethanoate while cooling.
(B) Calculate the value of $y$.
(C) The student repeated the experiment with a second sample of hydrated zinc ethanoate.

The student's calculations were correct but the value of $y$ was found to be different from the expected value.
Suggest a reason for this difference.
7. Phenolphthalein is an indicator that can be prepared by the reaction of phenol with phthalic anhydride.
(a) Phenolphthalein prepared by this method can have insoluble impurities present. It can be purified by recrystallisation from an aqueous ethanol solution.
(i) Outline the steps that should be carried out to recrystallise phenolphthalein.
(ii) Name a technique that could be used to determine if the recrystallised phenolphthalein is pure.
(b) The equation for the reaction is given below.

$$
\begin{array}{ccc}
2 \mathrm{C}_{6} \mathrm{H}_{6} \mathrm{O} & +\underset{8}{\mathrm{C}_{8} \mathrm{H}_{4} \mathrm{O}_{3}} \text { phenol } & \mathrm{C}_{20} \mathrm{H}_{14} \mathrm{O}_{4} \\
\text { phthalic } \\
\text { anhydride }
\end{array}+\begin{gathered}
\mathrm{H}_{2} \mathrm{O} \\
(\mathrm{GFM}=94 \mathrm{~g}) \\
(\mathrm{GFM}=148 \mathrm{~g})
\end{gathered}
$$

0.96 g of phenol is reacted with 1.05 g phthalic anhydride.

In an experimental procedure, the percentage yield of phenolphthalein was 58\%.

Calculate the mass, in grams, of phenolphthalein produced.
8. High levels of sugar in foods are associated with obesity. Sugars are also the basis of many medicines.
(a) Glucose-fructose syrup is a type of sugar that is added to many foods. It is a mixture of glucose and fructose.

The ring structures of glucose and fructose are shown below.

glucose

fructose
(i) Write the molecular formula for fructose.
(ii) Suggest, with reference to the structures, how ${ }^{1} \mathrm{H}$ NMR spectroscopy could be used to distinguish between glucose and fructose.
8. (continued)
(b) A more accurate representation of the structure of glucose, and its geometric isomer galactose, is shown below.

glucose

galactose

With reference to the structures shown, explain why sugars such as glucose and galactose have geometric isomers.
(c) The ring structure of glucose exists in equilibrium with its open-chain structure. The diagram below shows the open-chain structure of one optical isomer of glucose called D-glucose.


D-glucose
(i) State the number of chiral centres in D-glucose.
(ii) Draw an open-chain structural formula for an optical isomer of D-glucose.
8. (continued)
(d) Relenza is a sugar-based medicine used to treat the flu virus. It acts by attaching to an enzyme active site on the virus.

The structure of Relenza is shown.


Relenza
(i) Suggest how the functional groups circled on the Relenza molecule would bind with part of the enzyme active site.
(ii) The structure of the natural active compound, sialic acid, is shown.

sialic acid

Sialic acid binds to the same part of the enzyme active site as Relenza.

Circle the functional groups on the sialic acid molecule which are most likely to bind with the enzyme active site.
(An additional diagram, if required, can be found on Page 28)
9. A student devised the following reaction scheme starting with 1-methylcyclohexene.

(a) In reaction (1), 1-methylcyclohexene reacts with HBr to produce two compounds.
(i) Draw a structural formula for compound X .
(ii) Reaction (1) obeys Markovnikov's rule.

Explain, with reference to the carbocation intermediate, why compound X is the minor product in this reaction.
9. (continued)
(b) Suggest a reagent that could be used in reaction (2).
(c) Reaction (3) is likely to undergo an $S_{N} 1$ mechanism.

Using curly arrow notation, draw the mechanism for this reaction.
(d) Name compound Y.
10. An active ingredient in many stain removing products is the oxidising agent hydrogen peroxide, $\mathrm{H}_{2} \mathrm{O}_{2}$.
(a) In an experiment to determine the concentration of hydrogen peroxide present in a stain remover a student carried out a titration with acidified permanganate solution.

$$
2 \mathrm{MnO}_{4}^{-}+5 \mathrm{H}_{2} \mathrm{O}_{2}+6 \mathrm{H}^{+} \rightarrow 2 \mathrm{Mn}^{2+}+5 \mathrm{O}_{2}+8 \mathrm{H}_{2} \mathrm{O}
$$

$5 \cdot 0 \mathrm{~cm}^{3}$ of stain remover was pipetted into a $100 \mathrm{~cm}^{3}$ standard flask and made up to the mark with distilled water.
$20.0 \mathrm{~cm}^{3}$ samples were titrated with $0.030 \mathrm{moll}^{-1}$ permanganate solution until a permanent pink colour remained. The results are shown in the table.

|  | 1st titration | 2nd titration | 3rd titration |
| :--- | :---: | :---: | :---: |
| Initial burette <br> reading $\left(\mathrm{cm}^{3}\right)$ | 0.3 | 19.2 | 0.2 |
| Final burette <br> reading $\left(\mathrm{cm}^{3}\right)$ | 19.2 | 37.7 | 18.8 |
| Volume used <br> $\left(\mathrm{cm}^{3}\right)$ | 18.9 | 18.5 | 18.6 |

(i) Calculate the number of moles of hydrogen peroxide in $20.0 \mathrm{~cm}^{3}$ of the diluted solution of stain remover.
(ii) Calculate the concentration, in $\mathrm{moll}^{-1}$, of hydrogen peroxide in the undiluted stain remover.
10. (a) (continued)
(iii) The concentration of hydrogen peroxide determined by the student was less than the concentration stated on the label for the stain remover.

One possible source of error could be an inaccurate concentration of the permanganate solution.

Describe how the student would confirm the concentration of the permanganate solution.

10. (continued)
(b) Some of the molecules thought to be responsible for the colour of stains are shown.

blackcurrant stain

red wine stain


Using your knowledge of chemistry, suggest how the chemicals in a stain remover might work on these stains.
11. Nutmeg is a seed that is commonly used as a spice in cooking. The flavour of nutmeg is due to a number of different compounds.
(a) The oil in nutmeg, trimyristin, can be easily extracted and purified.

In an experiment to extract trimyristin, a student refluxed nutmeg powder in a suitable solvent. Removal of the solvent produced an impure sample of solid trimyristin.
(i) Suggest why an ether could be a suitable solvent to extract trimyristin oil from nutmeg.
(ii) Suggest why the mixture was heated under reflux.
(b) Myristicin is another compound that can be isolated from nutmeg. ${ }^{1} \mathrm{H}$ NMR analysis showed there to be seven proton environments and these are numbered on the skeletal formula shown.

(i) Suggest a possible chemical shift for the peak arising due to proton environment 1.
(ii) Identify a proton environment which would produce a doublet in the ${ }^{1} \mathrm{H}$ NMR spectrum.
11. (continued)
(c) Myristicin can be converted into compound X in two steps.

myristicin

compound X

Suggest the type of reaction occurring at each step.
Step 1:

Step 2:
[END OF QUESTION PAPER]

* X 713770127 *


## 2017 Chemistry

Advanced Higher

## Finalised Marking Instructions

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Detailed marking instructions for each question

## Section 1

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

## Section 2

| Question |  |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 1. | (a) | (i) | Electrons promoted/excited <br> (1) <br> Falls/moves/jumps to lower level <br> and <br> energy/photon(s)/light is emitted/ released <br> (1) | 2 |  |
|  |  | (ii) | Different (electron) transitions OR Different energy levels/subshells OR <br> Suitable diagram with explanation | 1 |  |
|  | (b) |  | 186 (kJ mol$^{-1}$ ) <br> 1 mark can be awarded for any one of the following: <br> $\mathrm{E}=\mathrm{Lhc} / 1000 \lambda$ <br> OR <br> $\mathrm{E}=$ Lhc $/ \lambda$ <br> OR <br> $f=c / \lambda$ and $E=\operatorname{Lhf}$ <br> OR $\frac{6.02 \times 10^{23} \times 6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{(1000 \times) 644 \times 10^{-9}}$ | 2 | Acceptable sig figs range is two to five: $\text { 190, } 185 \cdot 9,185 \cdot 93$ <br> Units not required but if given must be correct as stated in the question. |

## Go to Topic Grid

| Question |  |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2. | (a) | (i) | 0.0304 <br> Partial marks may be awarded for any of the following: $\begin{equation*} \left[\mathrm{PCl}_{5}\right]=0.0580 \tag{1} \end{equation*}$ <br> $\left[\mathrm{PCl}_{3}\right]\left[\mathrm{Cl}_{2}\right] /\left[\mathrm{PCl}_{5}\right]$ or substitution of values OR $\begin{equation*} 0.0420^{2} / 0.0580 \tag{2} \end{equation*}$ | 3 | Acceptable sig figs range is two to five: $0.030,0.03041,0.030414$ <br> Final answer must be a numerical value with no unit. A value given with a unit is incorrect. <br> Allow follow through for an incorrect value for $\left[\mathrm{PCl}_{5}\right]$ only if $\left[\mathrm{PCl}_{3}\right]$ and $\left[\mathrm{Cl}_{2}\right]$ are 0.0420 <br> Round brackets are not acceptable in the equilibrium expression for a partial mark. |
|  |  | (ii) | Forward reaction is favoured OR <br> More products formed/less reactants <br> OR <br> Equilibrium shifts to the right <br> (1) <br> K increases | 2 | Allow follow through from incorrect expression in (a)(i) |

## Go to Topic Grid

| Question |  | Answer | Max mark | Additional guidance |  |
| :--- | :--- | :--- | :--- | :---: | :--- |
| (b) | (i) |  |  | 1 | Must show square brackets <br> and negative charge on <br> outside of bracket <br> OR <br> negative charge on P with or <br> without brackets. <br> Wedges and dashes not |
| essential but if used must be |  |  |  |  |  |
| correct. |  |  |  |  |  |$|$



Go to Topic Grid

| Question |  |  | Answer |  | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (a) | (i) | 4, IV, +4, 4+, four |  | 1 |  |
|  |  | (ii) | $\frac{11}{15}$ | $\square$ | 1 | All of the orbital boxes opposite must be shown and clearly labelled. <br> Single or double headed arrows are acceptable. <br> Accept diagrams showing an empty 4s orbital box. <br> Allow follow through from (a)(i). |
|  | (b) | (i) | Rate | $\mathrm{k}\left[\mathrm{V}^{3+}(\mathrm{aq})\right]\left[\mathrm{Fe}^{3+}(\mathrm{aq})\right]$ | 1 | Accept without state symbols but if included they must be correct. <br> Must be a lower case k <br> Round brackets are not acceptable. |
|  |  | (ii) | (A) | Zero order / 0 <br> $\mathrm{Fe}^{3+}$ is not a reactant in slow step /RDS <br> OR <br> $\mathrm{Fe}^{3+}$ only appears in the fast step <br> (1) | 2 | If the order is incorrect then 0 marks are awarded. <br> If the order is not given then one mark may be awarded for a correct explanation. |

Go to Topic Grid

| Question | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: |
|  | (B) $\begin{aligned} & \text { It is in the same state as the ions } \\ & \text { in the reaction/named } \\ & \text { reactant(s)/reactant(s). }\end{aligned}$ | 1 |  |
| (c) | $92 \mathrm{mg} / 0.092 \mathrm{~g} / 9.2 \times 10^{-5} \mathrm{~kg}$ <br> A partial mark may be awarded for any of the following: $\begin{equation*} 92 / 0 \cdot 092 / 9 \cdot 2 \times 10^{-5} \tag{1} \end{equation*}$ <br> correct unit consistent with working | 2 | Acceptable sig figs range is one to four: $\begin{align*} & 90,92 \cdot 3,92 \cdot 30  \tag{2}\\ & 0.09,0.0923,0.09230 \\ & 9.0 \times 10^{-5}, 9 \cdot 23 \times 10^{-5}, \\ & 9.230 \times 10^{-5} \end{align*}$ <br> This mark for units is independent of general marking instruction (l). |



## Go to Topic Grid

| Question |  | Answer | Max mark | Additional guidance |  |
| :--- | :--- | :--- | :--- | :---: | :--- |
| 6. | (a) | (i) | $\begin{array}{l}\text { Both electrons/shared pair/bonding } \\ \text { electrons come from the same atom/ } \\ \text { species/molecule/ligand or from a } \\ \text { lone pair. }\end{array}$ | $\mathbf{1}$ | $\begin{array}{l}\text { An answer that refers to both } \\ \text { electrons being donated from } \\ \text { one atom to another atom } \\ \text { should not be awarded the } \\ \text { mark. }\end{array}$ |
| (ii) | $\begin{array}{l}\text { Any structure showing a copper ion } \\ \text { joined by 4 bonds to one ligand }\end{array}$ | $\mathbf{1}$ | $\begin{array}{l}\text { Structure of ligand must be } \\ \text { correct for mark to be } \\ \text { awarded. } \\ \text { Bonds must be between }\end{array}$ |  |  |
| copper and the nitrogen |  |  |  |  |  |\(\left.] \begin{array}{l}atoms for mark to be <br>

awarded. These can be solid <br>
lines, dotted lines, dashed or <br>
solid wedges. <br>
Shape of complex ion should <br>
be ignored. <br>
Charge is not needed but if <br>
included must be correct.\end{array}\right]\)

| Question |  | Answer |  | Max mark | Additional guidance |  |
| :--- | :--- | :--- | :--- | :--- | :--- | :--- |
| 6. | (b) | (iii) | (A) | desiccator | (2) | $\mathbf{2}$ |
| (B) | (y=) 2 <br> A partial mark may be awarded <br> for any of the following: <br> Correct moles: 0.023 (0.02279) <br> of zinc ethanoate and 0.046 of <br> water <br> OR |  |  |  |  |  |

## Go to Topic Grid

| Question |  |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (a) | (i) | All four points for 2 marks. Two or three points for 1 mark. <br> - minimum/small (volume) <br> - hot solvent/hot ethanol/hot ethanol (aq) <br> - filter (to remove impurities) <br> - cool | 2 | Filtration must be carried out before the cooling step. |
|  |  | (ii) | Melting point/mixed melting point <br> OR <br> IR <br> OR <br> NMR <br> OR <br> MS <br> OR <br> Chromatography/TLC | 1 | Boiling point is not acceptable |

## Go to Topic Grid

| Question | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: |
| (b) | $\begin{equation*} 0.94 \text { (g) } \tag{3} \end{equation*}$ <br> Partial marks may be awarded for any of the following: <br> Using correct mole ratio (2 to 1 phenol to phenolphthalein)/ idea of phthalic anhydride in excess. <br> Calculating theoretical yield <br> (1) <br> Using percentage yield to get final answer | 3 | Acceptable sig figs range is one to four: $0.9,0.942,0.9418$ <br> Units not needed for final answer but if given must be correct. <br> Follow through applies if phthalic anhydride is used as limiting reagent or correct mole ratio not applied; |

## Go to Topic Grid

| Question |  | Answer | Max mark | Additional guidance |  |
| :--- | :--- | :--- | :--- | :---: | :--- |
| 8. | (a) | (i) | (ii) | $\mathrm{C}_{6} \mathrm{H}_{12} \mathrm{O}_{6}$ <br> Any one of the following <br> concepts. <br> Different numbers of peaks/ <br> proton/hydrogen environments <br> OR <br> Different shift patterns <br> OR <br> Different splitting patterns/ <br> number of sub peaks <br> OR <br> Different peak area/heights/ <br> integrals | $\mathbf{1}$ |


| Question |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
|  | (ii) | Accept one, two, three or four chiral centre(s) reflected | 1 | General marking instruction (o) applies to this mark. <br> Expanded $\mathrm{CH}_{2} \mathrm{OH}$ group or reversed $\mathrm{HOH}_{2} \mathrm{C}$ group must be correct. <br> Condensed CHO group or reversed OHC group must be correct. <br> Do not accept three groups on any one carbon atom (particularly $\mathrm{C}_{5}$, the carbon atom adjacent to the $\mathrm{CH}_{2} \mathrm{OH}$ ) being 'swapped' round. |
| (d) | (i) | hydrogen bonding <br> OR <br> dative (covalent) bonding | 1 | Any other intermolecular force should not be treated as a cancelling error. <br> Ionic interactions is incorrect. |
|  | (ii) |  <br> A minimum of 2 of the 3 circled OH groups. | 1 | Any other functional groups circled is a cancelling error. |


| Question |  |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 9. | (a) | (i) |  | 1 | Accept any correct structural formula/stereoisomer. |
|  |  | (ii) | Less stable/unstable carbocation OR <br> More stable carbocation is tertiary/is more substituted/has alkyl group(s) | 1 | An answer that refers to the number of hydrogen atoms only, with no reference to the stability of a carbocation intermediate, is not acceptable. <br> An answer that refers to a more stable carbocation forming compound X , or a less stable carbocation forming the other/major compound, should be treated as a cancelling error. |
|  | (b) |  | $\mathrm{HCl}(\mathrm{aq}) /$ hydrochloric acid <br> OR <br> " $\mathrm{H}^{+}$and $\mathrm{H}_{2} \mathrm{O}$ " OR " $\mathrm{H}^{+} / \mathrm{H}_{2} \mathrm{O}$ " <br> OR <br> $\mathrm{H}^{+}(\mathrm{aq})$ <br> OR <br> any named (aqueous) acid/dilute acid | 1 | HCl on its own or any concentrated acid on its own is not acceptable. |


| Question | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: |
| (c) |   <br> This final structure is not required | 2 | 1 mark for intermediate including positive charge <br> 1 mark for the correct curly arrows with full arrow heads: First curly arrow, tail is from the bond and head is to the Br . Second curly arrow, tail is from the OH and head is towards the $\mathrm{C}^{+}$. |
| (d) | 1-methoxy-1-methylcyclohexane <br> OR <br> 1-methyl-1-methoxycyclohexane <br> OR <br> 1-methylmethoxycyclohexane <br> OR <br> methyl-1-methoxycyclohexane <br> OR <br> 1-methoxymethylcyclohexane <br> OR <br> methoxy-1-methylcyclohexane | 1 | Methoxymethylcyclohexane is not acceptable. <br> 1,1-methylmethoxycyclohexane and 1,1-methoxymethylcyclohexane are not acceptable. <br> Any name ending with "-ene" is not acceptable. |


| Question |  |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10. | (a) | (i) | $1.4 \times 10^{-3}(\mathrm{~mol})$ <br> A partial mark may be awarded for any of the following: $18.55 \times 10^{-3} \times 0.030=5.565 \times$ $10^{-4}$ moles $\mathrm{MnO}_{4}^{-}$in $20 \mathrm{~cm}^{3}$ <br> OR <br> Correct use of incorrect number of moles of permanganate to calculate moles $\mathrm{H}_{2} \mathrm{O}_{2}$ in $20 \mathrm{~cm}^{3}$ | 2 | Acceptable sig figs range is one to four: $\begin{align*} & 1 \times 10^{-3} / 1 \cdot 39 \times 10^{-3} /  \tag{2}\\ & 1 \cdot 391 \times 10^{-3} \end{align*}$ <br> Unit is not required but if given must be correct, mol. A unit of "mols" is not acceptable. |
|  |  | (ii) | $1 \cdot 4\left(\mathrm{~mol} \mathrm{l}^{-1}\right)$ <br> A partial mark may be awarded for any of the following: <br> $1.4 \times 10^{-3} \times 5=0.0070$ moles in $100 \mathrm{~cm}^{3}$ <br> OR <br> $200 \times$ incorrect number of moles to calculate concentration in $5 \mathrm{~cm}^{3}$ <br> OR $1.4 \times 10^{-3} / 0.02=0.07\left(\mathrm{~mol} \mathrm{l}^{-1}\right)$ <br> (diluted solution) <br> OR <br> $20 \times$ an incorrect concentration | 2 | Acceptable sig figs range is one to four: $\begin{equation*} 1 / 1 \cdot 39 / 1 \cdot 391 \tag{2} \end{equation*}$ <br> Allow follow through from (a)(i) by $\times 1000$. <br> Unit is not required but if given must be correct. |
|  |  | (iii) | Titrate with (named) standard solution/solution of known concentration <br> OR <br> Carry out colorimetry with a standard solution/solution of known concentration | 1 | If standard/known solution is named then it must be appropriate for a redox reaction, such as oxalic acid solution, hydrogen peroxide, etc. <br> Standardising the permanganate solution without mention of titration is not acceptable. |


| Question | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: |
| (b) | This is an open ended question <br> 1 mark: The student has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the chemistry within the problem is understood. <br> 2 marks: The student has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. <br> 3 marks: The maximum available mark would be awarded to a student who has demonstrated, at an appropriate level, a good understanding, of the chemistry involved. The student shows a good comprehension of the chemistry of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an <br> "excellent" answer or a <br> "complete" one. | 3 | Zero marks should be awarded if: <br> The student has demonstrated no understanding of the chemistry involved at an appropriate level. There is no evidence that the student has recognised the area of chemistry involved or has given any statement of a relevant chemistry principle. This mark would also be given when the student merely restates the chemistry given in the question. |


| Question |  |  | Answer | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 11. | (a) | (i) | similar polarities/both non-polar /similar intermolecular forces <br> OR <br> volatile/low boiling point/ evaporates easily <br> OR <br> Inert/unreactive/does not react | 1 | Both polar is not acceptable. <br> Ether is insoluble in water is not acceptable on its own but is not a cancelling error. <br> "It/trimyristin/ether is soluble" is not a sufficiently detailed response, on its own. |
|  |  | (ii) | to prevent vapours escaping OR to allow extended heating OR more vigorous heating OR to dissolve/extract maximum OR more efficient | 1 | "To prevent evaporation of ....." with no reference to escaping or leaving is not acceptable. |
|  | (b) | (i) | Any single value between 4.5 and $6 \cdot 0$ (inclusive) <br> OR <br> The range 4.5-6.0 | 1 |  |
|  |  | (ii) | 1 or 3 | 1 |  |
|  | (c) |  | Step 1: <br> (electrophilic) addition <br> (1) <br> Step 2: <br> (nucleophilic) substitution | 2 | If reactions and reagents given they must be correctly linked. <br> Additional for step 1 is not acceptable <br> Hydration for step 1 is not acceptable <br> Electrophilic substitution for step 2 is not acceptable |

[END OF MARKING INSTRUCTIONS]

MONDAY, 21 MAY
9:00 AM - 11:30 AM

Instructions for the completion of Section 1 are given on page 02 of your question and answer booklet X713/77/01.

Record your answers on the answer grid on page 03 of your question and answer booklet.
You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## SECTION 1 - 30 marks

## Attempt ALL questions

1. Which of the following is not a form of electromagnetic radiation?

A Beta
B Gamma
C Infrared
D Ultraviolet
2. The diagram represents the periodic table.


The shaded area is the
A s-block
B p-block
C d-block
D f-block.
3. A representation of a d-orbital is shown.


The maximum number of electrons that can occupy this orbital is
A 2
B 4
C 8
D 10 .
4. For the reaction

$$
\mathrm{BF}_{3}+\mathrm{F}^{-} \rightarrow \mathrm{BF}_{4}^{-}
$$

the three-dimensional arrangement of the bonds around the $B$ atom changes from
A trigonal pyramidal to square planar
B trigonal pyramidal to tetrahedral
C trigonal planar to square planar
D trigonal planar to tetrahedral.
5. Which of the following correctly shows the arrangement of the 3 d electrons in the $\mathrm{Ni}^{2+}$ ion in $\left[\mathrm{Ni}\left(\mathrm{H}_{2} \mathrm{O}\right)_{6}\right]^{2+}$ ?


B


C

6. Manganese has an oxidation number of +5 in

A $\mathrm{MnO}_{4}^{-}$
B $\mathrm{MnO}_{4}{ }^{2-}$
C $\mathrm{MnO}_{4}{ }^{3-}$
D $\mathrm{MnO}_{2}$
7. When sulfur dioxide and oxygen react the following equilibrium is established.

$$
2 \mathrm{SO}_{2}(\mathrm{~g})+\mathrm{O}_{2}(\mathrm{~g}) \rightleftharpoons 2 \mathrm{SO}_{3}(\mathrm{~g}) \quad \Delta H=-197 \mathrm{~kJ} \mathrm{~mol}^{-1}
$$

Which line in the table is correct if the temperature of the equilibrium mixture is increased?

|  | Equilibrium <br> constant, $K$ | Concentration of $\mathrm{SO}_{3}$ as <br> temperature increases |
| :---: | :---: | :---: |
| A | decreases | decreases |
| B | decreases | increases |
| C | increases | decreases |
| D | increases | increases |

8. $\mathrm{H}_{2} \mathrm{CO}_{3}(\mathrm{aq})+\mathrm{CN}^{-}(\mathrm{aq}) \rightleftharpoons \mathrm{HCN}(\mathrm{aq})+\mathrm{HCO}_{3}^{-}{ }^{-}(\mathrm{aq})$

Which line in the table correctly describes $\mathrm{H}_{2} \mathrm{CO}_{3}(\mathrm{aq})$ and $\mathrm{HCN}(\mathrm{aq})$ in the above reaction?

|  | $\mathrm{H}_{2} \mathrm{CO}_{3}(\mathrm{aq})$ | $\mathrm{HCN}(\mathrm{aq})$ |
| :---: | :---: | :---: |
| A | base | conjugate base |
| B | base | conjugate acid |
| C | acid | conjugate base |
| D | acid | conjugate acid |

9. What is the concentration of hydroxide ions, in $\mathrm{mol} \mathrm{l}^{-1}$, in a solution with a pH of $8 \cdot 5$ ?

A $8.5 \times 10^{-6}$
B $3.2 \times 10^{-6}$
C $8.5 \times 10^{-9}$
D $3.2 \times 10^{-9}$
10. Butanoic acid is a weak acid which dissociates as shown.

$$
\mathrm{C}_{3} \mathrm{H}_{7} \mathrm{COOH}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons \mathrm{C}_{3} \mathrm{H}_{7} \mathrm{COO}^{-}(\mathrm{aq})+\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})
$$

The equilibrium position can be shifted to the right by the addition of
A a catalyst
B sulfuric acid
C sodium hydroxide
D sodium butanoate.
11. Which of the following salts forms an alkaline solution in water?

A Sodium sulfate
B Lithium chloride
C Ammonium nitrate
D Potassium propanoate
12. Which of the following combinations would produce a buffer solution?

A Sodium chloride and ammonia
B Ammonium chloride and ammonia
C Sodium chloride and sodium hydroxide
D Ammonium chloride and sodium hydroxide
13. For which of the following reactions would the value of $\Delta G^{\circ}-\Delta H^{\circ}$ be closest to zero?
$\mathrm{A} \quad \mathrm{CaCO}_{3}(\mathrm{~s}) \rightarrow \mathrm{CaO}(\mathrm{s})+\mathrm{CO}_{2}(\mathrm{~g})$
B $\mathrm{C}(\mathrm{s})+\mathrm{H}_{2} \mathrm{O}(\mathrm{g}) \rightarrow \mathrm{CO}(\mathrm{g})+\mathrm{H}_{2}(\mathrm{~g})$
C $\mathrm{Zn}(\mathrm{s})+2 \mathrm{H}^{+}(\mathrm{aq}) \rightarrow \mathrm{Zn}^{2+}(\mathrm{aq})+\mathrm{H}_{2}(\mathrm{~g})$
D $\mathrm{Cu}^{2+}(\mathrm{aq})+\mathrm{Mg}(\mathrm{s}) \rightarrow \mathrm{Mg}^{2+}(\mathrm{aq})+\mathrm{Cu}(\mathrm{s})$
14. The following reaction is first order with respect to $P$ and second order with respect to $Q$.

$$
P+Q \rightarrow R+S
$$

Which of the following statements is not correct?
A The reaction is third order overall.
B The reaction occurs by a simple one step mechanism.
C The rate of the reaction decreases as the reaction proceeds.
D The rate of the reaction will double if the initial concentration of $P$ is doubled.
15.


Which of the following types of hybridisation occur in the above compound?
A $\mathrm{sp}^{3}$ only
B $\mathrm{sp}^{3}$ and sp
C $\mathrm{sp}^{3}$ and $\mathrm{sp}^{2}$
D $\mathrm{sp}^{3}, \mathrm{sp}^{2}$ and sp
16. Benzofuran is an important starting material in the manufacture of some medicines.

benzofuran

The gram formula mass of benzofuran is
A 124 g
B 120 g
C 118 g
D 114 g .
17. The diagram represents one enantiomer of an optically active compound where $\mathrm{W}, \mathrm{X}, \mathrm{Y}$ and $Z$ are four different groups.


Which of the following represents the other enantiomer of this compound?

A


B


C


D

18. The most appropriate reactants for the synthesis of $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{O}^{-} \mathrm{Na}^{+}$are

A sodium and butan-1-ol
B sodium and butanoic acid
C sodium hydroxide and butan-1-ol
D sodium hydroxide and butanoic acid.
19.


The above reaction is an example of
A hydration
B oxidation
C hydrolysis
D hydrogenation.
20. 18 g of an oxide of copper contains 16 g of copper.

The empirical formula of this oxide is
A $\mathrm{Cu}_{4} \mathrm{O}$
B $\mathrm{Cu}_{2} \mathrm{O}$
C $\mathrm{CuO}_{2}$
D $\mathrm{CuO}_{4}$.
21. A simplified mass spectrum of an organic compound is shown below.


Which of the following compounds could not have produced this spectrum?
A $\mathrm{CH}_{3} \mathrm{OCOCH}_{3}$
B $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{COOH}$
C $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{NH}_{2}$
D $\mathrm{CH}_{3} \mathrm{CH}(\mathrm{OH}) \mathrm{CH}_{2} \mathrm{CH}_{3}$
22.

eugenol

The infrared spectrum of eugenol would not be predicted to have an absorption in the wavenumber range

A $3100-3000 \mathrm{~cm}^{-1}$
B $\quad 2962-2853 \mathrm{~cm}^{-1}$
C $1730-1717 \mathrm{~cm}^{-1}$
D $1150-1070 \mathrm{~cm}^{-1}$.
23. Salbutamol is used to treat asthma. It behaves like the body's natural active compound by triggering a response in the muscles of the airways.
Salbutamol is
A an agonist
B an antagonist
C an inhibitor
D a receptor.
24. $200 \mathrm{~cm}^{3}$ of water is added to $50 \mathrm{~cm}^{3}$ of $2 \mathrm{~mol} \mathrm{l}^{-1}$ sodium hydroxide solution.

The concentration of the diluted sodium hydroxide solution in $\mathrm{mol} \mathrm{l}^{-1}$, is
A 0.5
B 0.4
C 0.2
D $0 \cdot 1$.
25. For solvent extraction from an aqueous solution, the solvent used should be immiscible with water and relatively unreactive.
Which of the following would be the most suitable solvent?
A $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CHO}$
B $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OCH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3}$
C $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{COOH}$
D $\mathrm{CH}_{3} \mathrm{CH}(\mathrm{OH}) \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}_{3}$
26. Which of the following is not a step in a recrystallisation technique?

A Allow the filtrate to cool slowly.
B Filter the hot solution to remove insoluble impurities.
C Dissolve the crystals in a minimum of hot solvent.
D Test the filtrate to ensure no more precipitate forms.
27. The melting point of an impure substance was determined to be $111^{\circ} \mathrm{C}-114^{\circ} \mathrm{C}$. After purification, the melting point should be

A higher and over a wider range
B higher and over a narrower range
C lower and over a wider range
D lower and over a narrower range.
28. During the technique of heating to constant mass, the purpose of the desiccator is to

A prevent reaction with oxygen in the air
B remove water from the compound
C prevent reabsorption of water
D prevent decomposition.
29. Using thin-layer chromatography, the components of a sample can be identified by $R_{f}$ values.

Which of the following affects the $R_{f}$ value for an individual component?
A The distance moved by the solvent.
B The concentration of the sample.
C The length of TLC plate.
D The solvent used.
30. Which of the following diagrams shows the apparatus correctly set up for heating under reflux?
A

B

C

D

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET]

1. Roman pottery contains traces of metals.
(a) The metals present in Roman pottery can be identified using atomic emission spectroscopy.
Analysis of a sample from a Roman pot produced a series of spectral lines. The data in the table shows the results for three of the spectral lines produced.

| Metal | Wavelength of <br> spectral line $(\mathrm{nm})$ | Relative intensity |
| :---: | :---: | :---: |
| aluminium | 620 | 651 |
|  | 589 | 485 |
| titanium | 498 | 375 |

(i) Name the metal that produces the orange-yellow spectral line at 589 nm .
(ii) A fourth line observed in the spectrum obtained from the Roman pot sample was caused by a transition with an energy value of $282 \mathrm{~kJ} \mathrm{~mol}^{-1}$.
Calculate the wavelength, in nm, of this spectral line.
(iii) The Roman pot sample was found to have a titanium content of $435 \mathrm{mg} \mathrm{kg}^{-1}$.
A different pot sample produced a spectral line at 498 nm with a relative intensity of 75 .
Calculate the titanium content, in $\mathrm{mg} \mathrm{kg}^{-1}$, for this sample.

1. (continued)
(b) The Romans may have inadvertently made aluminium metal while producing pottery.

Aluminium has the following electronic configuration.

$$
1 s^{2} 2 s^{2} 2 p^{6} 3 s^{2} 3 p^{1}
$$

(i) This electronic configuration is consistent with the aufbau principle.
State the aufbau principle.
(ii) For the $3 p$ electron in aluminium, complete the table to show one possible set of values for the four quantum numbers.

| Quantum number | $n$ | $l$ | $m$ | $s$ |
| :---: | :---: | :---: | :---: | :---: |
| Value |  |  |  |  |
|  |  |  |  |  |

2. Apple jam contains malic acid.

malic acid
(a) Malic acid dissociates in two stages. The equation for the first stage dissociation of malic acid is
$\mathrm{HOOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COOH}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons \mathrm{HOOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}^{-}(\mathrm{aq})+\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})$
(i) Write an expression for the first stage dissociation constant, $K_{\mathrm{a}}$, for malic acid.
(ii) Complete the equation to show the second stage dissociation of malic acid.
$\mathrm{HOOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}^{-}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons$
3. (continued)
(b) While making apple jam, the jam will only thicken if the pH is between $2 \cdot 7$ and $3 \cdot 3$.
(i) The pH of the apple jam is determined by the first stage dissociation of malic acid $\left(K_{a}=3.2 \times 10^{-4}\right)$.
The concentration of malic acid in the jam is $0.0051 \mathrm{~mol}^{-1}$.
Show by calculation that the jam will thicken at this concentration of malic acid.
4. (b) (continued)
(ii) Pectin is a natural polymer found in apples which helps jam to thicken.

Part of the structure of pectin is shown.


Pectin binds to itself to help the jam thicken.
Suggest how the hydroxyl groups allow pectin molecules to bind.
3. Sodium carbonate can exist as different hydrated salts with the general formula $\mathrm{Na}_{2} \mathrm{CO}_{3} \cdot \mathrm{nH}_{2} \mathrm{O}$.
To determine $n$ in the general formula, a $250 \mathrm{~cm}^{3}$ solution containing 8.10 g of hydrated sodium carbonate was prepared. $25.0 \mathrm{~cm}^{3}$ samples of this solution were titrated with $0.358 \mathrm{~mol} \mathrm{l}^{-1}$ hydrochloric acid.

$$
\mathrm{Na}_{2} \mathrm{CO}_{3}(\mathrm{aq})+2 \mathrm{HCl}(\mathrm{aq}) \rightarrow 2 \mathrm{NaCl}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell)+\mathrm{CO}_{2}(\mathrm{~g})
$$

The following results were obtained.

| Titre | Volume of HCl added <br> $\left(\mathrm{cm}^{3}\right)$ |
| :---: | :---: |
| 1 | $20 \cdot 2$ |
| 2 | 19.5 |
| 3 | 19.4 |

(a) Describe the procedure for the accurate preparation of the $250 \mathrm{~cm}^{3}$ solution from the weighed sample of hydrated sodium carbonate.

## 3. (continued)

(b) (i) Calculate the number of moles of sodium carbonate in the $250 \mathrm{~cm}^{3}$ solution.
(ii) Calculate the value of $n$ in the formula $\mathrm{Na}_{2} \mathrm{CO}_{3} \cdot n \mathrm{H}_{2} \mathrm{O}$
3. (continued)
(c) Titration is a very useful analytical technique for volumetric analysis.

Using your knowledge of chemistry, discuss factors which should be considered when selecting appropriate chemicals for a titration.
4. But-2-yne and but-1-yne can undergo addition reactions with hydrogen using a palladium-based catalyst.

but-2-yne

but-1-yne
(a) State how transition metals can act as catalysts.
(b) In the reaction of but-2-yne with hydrogen, cis-but-2-ene is formed. Draw the skeletal structure of cis-but-2-ene.
(c) In the reaction of but-1-yne with hydrogen, but-1-ene is formed.

Explain why but-1-ene has no geometric isomers.
4. (continued)
(d) The equation for the hydrogenation of but-2-yne is shown.

$$
\mathrm{C}_{4} \mathrm{H}_{6}(\mathrm{l})+\mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{C}_{4} \mathrm{H}_{8}(\mathrm{~g})
$$

| Substance | Standard free energy of <br> formation, $\Delta G^{\circ}$ <br> $\left(\mathrm{kJ} \mathrm{mol}_{\mathrm{f}} \mathrm{m}\right)$ | Standard enthalpy of <br> formation, $\Delta H^{\circ}$ <br> $\left(\mathrm{kJ} \mathrm{mol}_{\mathrm{f}}\right)$ |
| :---: | :---: | :---: |
| $\mathrm{C}_{4} \mathrm{H}_{6}(\ell)$ | 185 | 119 |
| $\mathrm{H}_{2}(\mathrm{~g})$ | 0 | 0 |
| $\mathrm{C}_{4} \mathrm{H}_{8}(\mathrm{~g})$ | 65.9 | -6.99 |

(i) For the hydrogenation of but-2-yne, use the data in the table to calculate:
(A) the standard enthalpy change, $\Delta H^{\circ}$, in $\mathrm{kJ} \mathrm{mol}{ }^{-1}$;
(B) the standard entropy change, $\Delta S^{\circ}$.
4. (d) (continued)
(ii) Calculate the temperature, in K , below which this reaction is feasible.
5. Some dyes contain molecules that are coloured.

The structures of two different dye molecules are shown below.

(a) State the structural feature present that is responsible for the colour of these dye molecules.
(b) Explain fully how colour arises in these dye molecules.
5. (continued)
(c) A third dye molecule has the following structure.


Explain fully why this dye molecule will absorb a shorter wavelength of light than the other two dye molecules.
6. Ligands can be used in medicine and in quantitative analysis.
(a) Explain how ligands bond to metal ions to form complexes.
(b) DMPS is a ligand that can be used to treat mercury poisoning.


DMPS
(i) Write the molecular formula for DMPS.
6. (b) (continued)
(ii) A possible structure for the mercury-DMPS complex is

(A) State the term used to classify the DMPS ligand in this complex.
(B) State the co-ordination number of mercury in this complex.
6. (continued)
(c) Nisil is an alloy of nickel and silicon.

The mass of nickel in the Nisil alloy can be determined by quantitative analysis using a procedure in which the ligand dimethylglyoxime forms a solid complex with nickel ions. This complex is collected, dried and weighed.

nickel-dimethylglyoxime complex GFM 288.7 g
(i) Name the type of quantitative analysis being carried out.
(ii) It was found that 1.02 g of Nisil alloy formed 4.82 g of the complex. Calculate the percentage by mass of nickel in the alloy.
7. Adrenaline is a natural hormone produced in the body.

(a) Adrenaline can be artificially synthesised in the process shown below.

Step 1


## Step 2



## Step 3


7. (a) (continued)
(i) Suggest the type of chemical reaction taking place in step 1.
(ii) The aromatic product formed in step 2 contains an amine functional group.
State the type of amine formed.
(iii) Name reagent X used in step 3 .
(iv) Identify the step(s) in which the product has a carbon chiral centre.
7. (continued)
(b) Adrenaline is used as a treatment for severe allergic reactions.

A typical dose contains $0.3 \mathrm{~cm}^{3}$ of 500 ppm adrenaline solution.
Calculate the mass of adrenaline, in mg , delivered in one dose.
(c) Adrenaline can be extracted from the leaves of the agnimantha plant. The adrenaline extracted can be identified using thin layer chromatography, TLC.
Complete and label the diagram to show how the TLC should be set up to compare the extracted adrenaline with a sample of pure adrenaline.
(An additional diagram, if required, can be found on page 36).

8. Ethanol biofuel can be made from corn starch. The flow diagram shows the steps involved in the production of ethanol biofuel.

(a) Step 1 produces a solution with a concentration of $13 \%$ ethanol by volume. This can be checked by measuring the density of the solution and comparing it to a calculated value. The density of the solution can be calculated using the following expression.

$$
d=\frac{m_{1}+m_{2}}{100} \quad \begin{aligned}
& d=\text { density of solution, in } \mathrm{g} \mathrm{~cm}^{-3} \\
& m_{1}=\text { mass of ethanol, in } \mathrm{g}, \text { in } 100 \mathrm{~cm}^{3} \text { of solution } \\
& m_{2}=\text { mass of water, in } \mathrm{g}, \text { in } 100 \mathrm{~cm}^{3} \text { of solution }
\end{aligned}
$$

Mass of $1 \mathrm{~cm}^{3}$ of ethanol $=0.79 \mathrm{~g} \quad$ Mass of $1 \mathrm{~cm}^{3}$ of water $=1.00 \mathrm{~g}$

Calculate the density of the ethanol solution, in $\mathrm{g} \mathrm{cm}^{-3}$, formed in step 1.2
8. (continued)
(b) In step 2, 96\% ethanol solution is produced by distillation.

Suggest why pure ethanol biofuel cannot be obtained from an ethanol/water mixture by distillation alone.
(c) Step 3 uses a molecular sieve to remove water from the 96\% ethanol solution.

Part of the structure of a molecular sieve is shown.


Suggest how this molecular sieve could remove the water.
8. (continued)
(d) Ethanol can also be prepared by a nucleophilic substitution reaction.

Using your knowledge of chemistry, discuss the role of nucleophilic substitution reactions in the preparation of other chemicals.
9. A mixture of butan-1-ol and butan-2-ol can be synthesised from 1-bromobutane in a two-stage process.


(a) Name the type of chemical reaction taking place in stage 1.
(b) Using structural formulae and curly arrow notation, outline a possible mechanism for the production of butan-2-ol in stage 2.
9. (continued)
(c) The high-resolution proton NMR spectrum for butan-2-ol is shown.


Circle the hydrogen atom(s) on the structure below responsible for the multiplet at 3.7 ppm .
(An additional structure, if required, can be found on page 36).

9. (continued)
(d) Butan-1-ol can also be synthesised from 1-bromobutane by a different type of chemical reaction.

An experiment was carried out to determine the kinetics for the reaction. Under certain conditions, the following results were obtained.

| $\left[\mathrm{C}_{4} \mathrm{H}_{9} \mathrm{Br}\right]\left(\mathrm{mol} \mathrm{l}^{-1}\right)$ | $\left[\mathrm{OH}^{-}\right]\left(\mathrm{mol} \mathrm{l}^{-1}\right)$ | Initial rate $\left(\mathrm{mol} \mathrm{l}^{-1} \mathrm{~s}^{-1}\right)$ |
| :---: | :---: | :---: |
| 0.25 | 0.10 | $3.3 \times 10^{-6}$ |
| 0.50 | 0.10 | $6.6 \times 10^{-6}$ |

(i) The reaction is first order with respect to both reactants.

Write the overall rate equation for the reaction.
(ii) Calculate the value for the rate constant, $k$, including the appropriate units.
10. Decamethylcobaltocene is a powerful reducing agent.



decamethylcobaltocene
(a) The ligand in decamethylcobaltocene has an aromatic ring. State the feature that provides stability to aromatic rings.
(b) Write the electronic configuration, in terms of $\mathrm{s}, \mathrm{p}$ and d orbitals, for $\mathrm{Co}^{2+}$ in this complex ion.
10. (continued)
(c) Decamethylcobaltocene can be dissolved in petroleum ether to produce a coloured solution. The concentration of this solution can be determined using colorimetry.
(i) (A) The first stage is to prepare a calibration graph.

Describe fully the procedure required to obtain results that would allow a calibration graph to be drawn.
(B) The second stage is to determine the concentration of a sample of the decamethylcobaltocene solution.

Describe how this would be carried out.
(ii) Name the compound produced when decamethylcobaltocene solution reduces propanal.
10. (continued)
(d) Decamethylcobaltocene oxidises easily creating impurities in the sample.

The purity of decamethylcobaltocene can be checked using low-resolution ${ }^{1} \mathrm{H}$ NMR.


decamethylcobaltocene

Predict the number of peaks that would be observed in a low-resolution ${ }^{1} \mathrm{H}$ NMR spectrum of a pure sample of decamethylcobaltocene.

## 2018 Chemistry

## Advanced Higher

## Finalised Marking Instructions

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Detailed marking instructions for each question

## Section 1

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

## Section 2



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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2. | (a) | (i) | $K=\frac{\left[\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})\right]\left[\mathrm{HOOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COO} \cdot(\mathrm{aq})\right]}{\left[\mathrm{HOOCCH}{ }_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COOH}(\mathrm{aq})\right]}$ | 1 | Molecular formula or structure are both acceptable. <br> State symbols are not required but if shown, they must be correct. <br> Square brackets must be used. <br> ' $k$ ' instead of ' $K$ ' would not be acceptable. <br> The inclusion of $\left[\mathrm{H}_{2} \mathrm{O}\right]$ is not acceptable. <br> $\left[\mathrm{H}^{+}\right]$is acceptable instead of $\left[\mathrm{H}_{3} \mathrm{O}^{+}\right]$ |
|  |  | (ii) | $\mathrm{HOOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}^{-}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons$ | $\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq}$ <br> 1 | $+{ }^{-\mathrm{OOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}^{-}(\mathrm{aq})}$ <br> Correct H must be removed. $\left(\mathrm{OOCCH}_{2} \mathrm{CH}(\mathrm{OH}) \mathrm{COO}\right)^{2-}$ <br> is also acceptable for the conjugate base. <br> State symbols are not required but if shown, they must be correct. <br> [ $\mathrm{H}^{+}$] is not acceptable instead of $\left[\mathrm{H}_{3} \mathrm{O}^{+}\right.$] |

Go to Topic Grid


Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3. | (a) |  | Dissolve/make a solution of the sodium carbonate in distilled/ deionised water (in a beaker). <br> Transfer the solution/it and the rinsings. <br> Use of a ( $250 \mathrm{~cm}^{3}$ ) standard/ volumetric flask. <br> Make (the solution) up to the mark/line (in a standard/volumetric flask with distilled/deionised water). | 2 | 4 correct to get two marks. <br> 2 or 3 to get one mark. <br> One mention of distilled/deionised water and standard/volumetric flask anywhere in the answer is sufficient. <br> Either making a solution or dissolving must be mentioned before making up to the mark. <br> Mention of meniscus alone is not sufficient for making up to the mark. <br> Incorrect size of standard flask is a cancelling error for standard flask. |
|  | (b) | (i) | 0.0348 (moles $/ \mathrm{mol}$ ) <br> One partial mark may be awarded for: <br> Multiplying by $0.01945 \text { or } 19.45 / 1000$ <br> OR <br> multiplying a calculated number of moles by 10 <br> OR <br> correct application of mole ratio. | 2 | $0.035 / 0.03482 / 0.034816$ are also acceptable answers. <br> If a candidate uses 19.4 or 19.5 then a maximum of 1 mark can be awarded. <br> General marking instruction (l) applies. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3. | (b) | (ii) | 7 <br> One partial mark may be awarded for: <br> calculating mass of water in the sample $=4.41 \mathrm{~g}$ <br> OR <br> calculating mass of water in the GFM for the sample $=126.76 \mathrm{~g}$ <br> OR <br> correctly calculating a mass of water from $b(i)$ <br> OR <br> correct ratio $\mathrm{Na}_{2} \mathrm{CO}_{3}: \mathrm{H}_{2} \mathrm{O}$ from a calculated mass /moles of water. | 2 | Value for n must be a whole number. <br> Allow follow through from b(i). |

Go to Topic Grid

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 3. | (c) | This is an open ended question. <br> 1 mark: The student has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the chemistry within the problem is understood. <br> 2 marks: The student has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. <br> 3 marks: The maximum available mark would be awarded to a student who has demonstrated, at an appropriate level, a good understanding, of the chemistry involved. The student shows a good comprehension of the chemistry of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one. | 3 | Zero marks should be awarded if: <br> - the student has demonstrated no understanding of the chemistry involved at an appropriate level. <br> - there is no evidence that the student has recognised the area of chemistry involved or has given any statement of a relevant chemistry principle. <br> This mark would also be given when the student merely restates the chemistry given in the question. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 4. | (a) |  | unpaired d electrons <br> OR <br> empty/half-filled/incomplete d orbitals/subshell <br> OR variable oxidation states OR <br> donating and accepting electrons. | 1 | Mention of the formation of intermediates or providing a surface area for a reaction or lowering the activation energy would not be awarded a mark but are not cancelling errors. |
|  | (b) |  |  | 1 | Any orientation is acceptable. |
|  | (c) |  | But-1-ene has two hydrogens/the same group on first carbon of the $\mathrm{C}=\mathrm{C}$ <br> OR <br> But-1-ene has three hydrogens attached to the $\mathrm{C}=\mathrm{C}$ <br> OR <br> swapping any of the groups on the $\mathrm{C}=\mathrm{C}$ results in the same structure. | 1 |  |
|  | (d) | (i) <br> (A) | $-126\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ | 1 | -130/-126.0/-125•99 also acceptable answers. <br> Units are not required but if included must be correct. |

Go to Topic Grid


Go to Topic Grid

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 5. | (a) | Conjugated system <br> OR <br> alternating double and single bonds. | 1 | Accept a description of a conjugated system. <br> Chromophore on its own is not enough for the mark to be awarded. |
|  | (b) | Electrons move from HOMO to LUMO. <br> Absorption of light (from the visible part of the spectrum) means that light of the complementary colour is seen. | 2 | The direction of electron transitions must be given. <br> Any mention of emission or dropping energy levels is a cancelling error for the second mark. |
|  | (c) | There is less conjugation <br> OR <br> a shorter sequence of alternating double and single bonds <br> OR <br> a smaller chromophore. <br> Larger gap/greater energy (absorbed). | 2 | "Fewer double bonds" by itself would not be awarded the first mark. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 6. | (a) |  | (Ligands) donate (lone/non-bonding) pairs of electrons (to the metal ion) OR <br> (ligands) can form dative covalent bonds (with the metal ion). | 1 | Any mention of donating a bonding pair of electrons is a cancelling error. |
|  | (b) | (i) | $\mathrm{C}_{3} \mathrm{H}_{8} \mathrm{O}_{3} \mathrm{~S}_{3}$ | 1 | Any order of elements in the formula is acceptable. |
|  |  | $\begin{gathered} \text { (ii) } \\ \mathrm{A} \end{gathered}$ | Bidentate | 1 |  |
|  |  | $\begin{gathered} \text { (ii) } \\ \text { B } \end{gathered}$ | 4/IV/four | 1 | Charges are not acceptable. |
|  | (c) | (i) | gravimetric (analysis) | 1 |  |
|  |  | (ii) | 96•1(\%) <br> Partial marking <br> One mark can be awarded for: <br> mass of nickel $=0.980(\mathrm{~g})$ <br> OR <br> any calculated number divided by 1.02 and multiplied by 100 <br> OR <br> $61 \cdot 1 \mathrm{~g}$ of the alloy can make 1 mole of the complex <br> OR <br> 58.7 divided by a calculated mass of alloy and multiplied by 100 . | 2 | 96/96.08/96.081 are also acceptable answers. <br> General marking instruction (l) applies. |

Go to Topic Grid

| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (a) | (i) | (Electrophilic) substitution | 1 | Nucleophilic is a cancelling error. |
|  |  | (ii) | Secondary | 1 |  |
|  |  | (iii) | Lithium aluminium hydride OR $\mathrm{LiAlH}_{4}$ | 1 |  |
|  |  | (iv) | (Step) 3 | 1 |  |
|  | (b) |  | $0 \cdot 2$ (mg) | 1 | 0.15 (mg) is also an acceptable answer. <br> Answer must be expressed in milligrams, mg. <br> Units not required but must be correct if given. |
|  | (c) |  | The diagram must show labelled start positions (eg spots, crosses or letters) of the extract and pure, on a horizontal line above the level of the solvent. | 1 |  |

Go to Topic Grid

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 8. | (a) | $0.97\left(\mathrm{~g} \mathrm{~cm}^{-3}\right)$ <br> Partial Marking: <br> One mark can be awarded for: <br> Mass of ethanol $=10 \cdot 27$ <br> AND <br> Mass of water $=87$ <br> OR <br> correctly calculating the density using one correct mass and one incorrect mass. | 2 | 1/0.973/0.9727 are also acceptable answers. <br> Units not required but if given must be correct. |
|  | (b) | Boiling points are similar OR <br> (some) water evaporates at ethanol's boiling point <br> OR <br> any mention of attraction or forces between water (molecules) and ethanol (molecules). | 1 |  |
|  | (c) | Water (molecules) are smaller than ethanol (molecules) <br> OR <br> ethanol (molecules) are too large to pass through <br> OR <br> ethanol (molecules) are larger than water (molecules) <br> OR <br> water (molecules) pass through but ethanol (molecules) cannot <br> OR <br> water (molecules) are trapped in the sieve. | 1 | An acceptable answer should demonstrate an understanding of the difference in size between water molecules and ethanol molecules. |

Go to Topic Grid

| Que | tion | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 8. | (d) | This is an open ended question. <br> 1 mark: The student has demonstrated, at an appropriate level, a limited understanding of the chemistry involved. The student has made some statement(s) which is/are relevant to the situation, showing that at least a little of the chemistry within the problem is understood. <br> 2 marks: The student has demonstrated, at an appropriate level, a reasonable understanding of the chemistry involved. The student makes some statement(s) which is/are relevant to the situation, showing that the problem is understood. <br> 3 marks: The maximum available mark would be awarded to a student who has demonstrated, at an appropriate level, a good understanding, of the chemistry involved. The student shows a good comprehension of the chemistry of the situation and has provided a logically correct answer to the question posed. This type of response might include a statement of the principles involved, a relationship or an equation, and the application of these to respond to the problem. This does not mean the answer has to be what might be termed an "excellent" answer or a "complete" one. | 3 | Zero marks should be awarded if: <br> - the student has demonstrated no understanding of the chemistry involved at an appropriate level. <br> - there is no evidence that the student has recognised the area of chemistry involved or has given any statement of a relevant chemistry principle. <br> This mark would also be given when the student merely restates the chemistry given in the question. |


| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 9. | (a) |  | (Base induced) elimination | 1 |  |
|  | (b) |  |  <br> OR <br> One mark for the curly arrow from double bond to hydrogen ion $/ \mathrm{H}_{3} \mathrm{O}^{+}$ <br> One mark for correct carbocation (1) <br> One mark for two curly arrows showing water attacking and hydrogen being removed from the water | 3 <br> C | Accept correct structures with an ethyl group, $-\mathrm{C}_{2} \mathrm{H}_{5}$. <br> Connectivity for an ethyl group must be correct for the intermediate carbocation. <br>  |

Go to Topic Grid


Go to Topic Grid

| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :---: | :--- |$|$| 10. | (a) |
| :--- | :--- |
|  | (b) |

[END OF MARKING INSTRUCTIONS]

```
FRIDAY, 10 MAY
9:00 AM - 11:30 AM
```

Instructions for the completion of Section 1 are given on page 02 of your question and answer booklet X713/77/01.

Record your answers on the answer grid on page 03 of your question and answer booklet.
You may refer to the Chemistry Data Booklet for Higher and Advanced Higher.
Before leaving the examination room you must give your question and answer booklet to the Invigilator; if you do not, you may lose all the marks for this paper.

## SECTION 1 - 30 marks

## Attempt ALL questions

1. In an emission spectrum of mercury, the line at 310 nm is due to

A energy from the ultraviolet region of the electromagnetic spectrum being absorbed
B energy from the ultraviolet region of the electromagnetic spectrum being released
C energy from the visible region of the electromagnetic spectrum being absorbed
D energy from the visible region of the electromagnetic spectrum being released.
2. In which of the following changes would heating to constant mass allow the mass of water produced to be determined?

A $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{OH}(\ell) \rightarrow \mathrm{C}_{2} \mathrm{H}_{4}(\mathrm{~g})+\mathrm{H}_{2} \mathrm{O}(\ell)$
$\mathrm{B} \mathrm{CH}_{4}(\mathrm{~g})+2 \mathrm{O}_{2}(\mathrm{~g}) \rightarrow \mathrm{CO}_{2}(\mathrm{~g})+2 \mathrm{H}_{2} \mathrm{O}(\ell)$
C $\mathrm{KOH}(\mathrm{aq})+\mathrm{HCl}(\mathrm{aq}) \rightarrow \mathrm{KCl}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell)$
D $\mathrm{Na}_{2} \mathrm{CO}_{3} \cdot 10 \mathrm{H}_{2} \mathrm{O}(\mathrm{s}) \rightarrow \mathrm{Na}_{2} \mathrm{CO}_{3}(\mathrm{~s})+10 \mathrm{H}_{2} \mathrm{O}(\mathrm{l})$
3. Which of the following reagents would be most suitable for the gravimetric determination of magnesium ions in water?

A Sodium nitrate
B Silver(I) nitrate
C Sodium carbonate
D Silver(I) carbonate
4. Hund's rule states that

A electrons occupy degenerate orbitals singly with parallel spins before pairing
B no two electrons in an atom can have the same set of four quantum numbers
C electrons occupy orbitals in order of increasing energy
D the energy of an electron in an atom is quantised.
5. Which of the following molecules contains the smallest bond angle?

A $\mathrm{BeCl}_{2}$
B $\mathrm{BCl}_{3}$
C $\mathrm{CCl}_{4}$
D $\mathrm{PCl}_{5}$
6. Iron forms both $\mathrm{Fe}^{2+}$ and $\mathrm{Fe}^{3+}$ ions.

Which of the following statements is correct?
A $\mathrm{Fe}^{2+}$ ions have more occupied energy levels than $\mathrm{Fe}^{3+}$ ions
B $\mathrm{Fe}^{2+}$ ions have more unpaired electrons than $\mathrm{Fe}^{3+}$ ions
C $\mathrm{Fe}^{3+}$ ions are a better reducing agent than $\mathrm{Fe}^{2+}$ ions
D $\mathrm{Fe}^{3+}$ ions are more stable than $\mathrm{Fe}^{2+}$ ions
7. Which metal in the following ions has the highest oxidation state?

A $\mathrm{Cr}_{2} \mathrm{O}_{7}{ }^{2-}$
B $\quad \mathrm{MnO}_{4}^{-}$
C $\mathrm{VO}^{2+}$
D $\mathrm{Sn}^{4+}$
8. The copper complex shown can be used as a green food colouring.


Which line in the table is correct for this complex?

|  | Co-ordination <br> number of copper | Classification of <br> ligand |
| :---: | :---: | :---: |
| A | 2 | monodentate |
| B | 2 | tetradentate |
| C | 4 | monodentate |
| D | 4 | tetradentate |

9. $2 \mathrm{X}(\mathrm{g}) \rightleftharpoons \mathrm{Y}(\mathrm{g}) \quad \Delta H=-220 \mathrm{~kJ} \mathrm{~mol}^{-1}$

Which of the following changes will cause the equilibrium constant to increase?
A Decrease in temperature
B Increase in temperature
C Decrease in pressure
D Increase in pressure
10. The following graph shows the variation in $\Delta G$ with temperature ( $T$ ) for a reaction.


Which of the following statements is true?
A The reaction is never feasible
B The reaction is always feasible
C The reaction is feasible above 300 K
D The reaction is feasible below 300 K
11. Iron(III) oxide can be reduced to iron using hydrogen.

$$
\mathrm{Fe}_{2} \mathrm{O}_{3}(\mathrm{~s})+3 \mathrm{H}_{2}(\mathrm{~g}) \rightarrow 2 \mathrm{Fe}(\mathrm{~s})+3 \mathrm{H}_{2} \mathrm{O}(\mathrm{~g})
$$

| Substance | $\Delta \boldsymbol{H}_{\mathrm{f}}{ }^{\circ}\left(\mathbf{k J ~ m o l}^{-1}\right)$ |
| :---: | :---: |
| $\mathrm{Fe}_{2} \mathrm{O}_{3}(\mathrm{~s})$ | -822 |
| $\mathrm{H}_{2}(\mathrm{~g})$ | 0 |
| $\mathrm{Fe}(\mathrm{s})$ | 0 |
| $\mathrm{H}_{2} \mathrm{O}(\mathrm{g})$ | -242 |

The enthalpy change, $\Delta H^{\circ}$, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for the reduction of iron(III) oxide using hydrogen is
A $\quad-580$
B -96
C +96
D +580 .
12. Which line in the table is correct for water condensing?

|  | $\Delta \boldsymbol{H}$ | $\Delta \boldsymbol{S}$ |
| :---: | :---: | :---: |
| A | positive | negative |
| B | negative | negative |
| C | positive | positive |
| D | negative | positive |

13. The results in the table were obtained for the reaction

$$
X+2 Y \rightarrow Z
$$

| Experiment | $[\mathrm{X}]\left(\mathrm{moll}^{-1}\right)$ | $[\mathrm{Y}]\left(\mathrm{moll}^{-1}\right)$ | Initial rate $\left(\mathrm{moll}^{-1} \mathrm{~s}^{-1}\right)$ |
| :---: | :---: | :---: | :---: |
| 1 | 0.030 | 0.030 | 0.0064 |
| 2 | 0.060 | 0.030 | 0.0128 |
| 3 | 0.030 | 0.015 | 0.0064 |

From these results, the rate equation is
A rate $=\mathrm{k}[\mathrm{X}]$
B rate $=k[Y]$
C rate $=k[X][Y]$
D rate $=k[X][Y]^{2}$.
14. The rate of a chemical reaction is second order overall.

The units for the rate constant, $k$, are
A $\mathrm{moll}^{-1} \mathrm{~s}^{-1}$
B $\mathrm{Imol}^{-1} \mathrm{~s}^{-1}$
C $\mathrm{l}^{2} \mathrm{~mol}^{-2} \mathrm{~s}^{-1}$
D $\mathrm{l}^{-2} \mathrm{~mol}^{2} \mathrm{~s}^{-1}$.
15. The structure of 2-furonitrile is shown.


The number of pi bonds in 2-furonitrile is
A 2
B 3
C 4
D 7.
16. The structure of one form of vitamin B3 is shown.


The molecular formula of this structure is
A $\mathrm{C}_{6} \mathrm{H}_{5} \mathrm{O}_{2} \mathrm{~N}$
B $\mathrm{C}_{6} \mathrm{H}_{6} \mathrm{O}_{2} \mathrm{~N}$
C $\mathrm{C}_{7} \mathrm{H}_{5} \mathrm{O}_{2} \mathrm{~N}$
D $\mathrm{C}_{7} \mathrm{H}_{6} \mathrm{O}_{2} \mathrm{~N}$.
17. Which of the following compounds exhibits geometric isomerism?

A $\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}_{2} \mathrm{CH}=\mathrm{CH}_{2}$
B


C
$\mathrm{CH}_{3} \mathrm{CH}_{2} \mathrm{CH}=\mathrm{CHCH}_{3}$
D

18.


The systematic name of the molecule shown above is
A cis-2,3-diethylbut-2-ene
B trans-2,3-diethylbut-2-ene
C cis-3,4-dimethylhex-3-ene
D trans-3,4-dimethylhex-3-ene.
19. The structures shown below are isomeric amines.

trimethylamine

ethylmethylamine

Which line in the table is correct for trimethylamine when compared to ethylmethylamine?

|  | Boiling point | Solubility in water |
| :---: | :---: | :---: |
| A | higher | higher |
| B | higher | lower |
| C | lower | higher |
| D | lower | lower |

20. The reaction of butanone with lithium aluminium hydride produces

A butanoic acid
B butan-2-ol
C butan-1-ol
D butanal.
21.


Which line in the table is correct for the types of reaction taking place at steps 1,2 and 3 ?

|  | Step 1 | Step 2 | Step 3 |
| :---: | :---: | :---: | :---: |
| A | addition | reduction | condensation |
| B | electrophilic substitution | nucleophilic substitution | neutralisation |
| C | electrophilic substitution | reduction | condensation |
| D | addition | nucleophilic substitution | neutralisation |

22. Carboxylic acids can be prepared in different ways.

Which of the following is a suitable method for preparing a carboxylic acid in one reaction?
A Addition to an alkene
B Hydrolysis of a nitrile
C Reduction of an aldehyde
D Substitution of a haloalkane
23. A student attempted to predict the mass spectrum of propanone.

The predicted spectrum is shown below.


The actual mass spectrum of propanone contains only three main peaks.
Which of the above peaks would not appear in the actual mass spectrum?
24. Analysis of a compound shows the following percentage composition by mass.

$$
C=80 \cdot 0 \% \quad H=9 \cdot 3 \% \quad O=10 \cdot 7 \%
$$

The empirical formula for this compound is
A $\quad \mathrm{C}_{10} \mathrm{H}_{14} \mathrm{O}$
B $\quad \mathrm{C}_{14} \mathrm{H}_{10} \mathrm{O}$
C $\mathrm{C}_{14} \mathrm{H}_{20} \mathrm{O}$
D $\mathrm{C}_{20} \mathrm{H}_{14} \mathrm{O}$.
25.


Which of the following splitting patterns would be observed for the circled atom in the high resolution ${ }^{1} \mathrm{H}$ NMR spectrum of ethanol?

A Doublet
B Triplet
C Quartet
D Quintet

## Go to Topic Grid

26. Pramipexole is a drug used to treat the symptoms of Parkinson's disease. Pramipexole acts like a natural compound in the body, dopamine, to stimulate nerve cells.
Buprenorphine is a drug used to treat heroin addiction. Buprenorphine stimulates receptors in the body but produces less of a response compared to heroin.

Which line in the table best describes pramipexole and buprenorphine?

|  | Pramipexole | Buprenorphine |
| :---: | :---: | :---: |
| A | agonist | agonist |
| B | agonist | antagonist |
| C | antagonist | agonist |
| D | antagonist | antagonist |

27. The human nose can generally detect the toxic gas hydrogen sulfide at levels of 0.03 ppm . If a person inhales 6 litres of air per minute, containing 0.03 ppm of hydrogen sulphide, what mass of hydrogen sulfide is inhaled in 10 minutes?

A $\quad 2 \mathrm{~g}$
B 1.8 g
C $\quad 200 \mathrm{mg}$
D 1.8 mg
28. Which of the following techniques could be used to purify an impure sample of solid caffeine?

A Thin layer chromatography
B Heating under reflux
C Recrystallisation
D Distillation
29. When substance $X$ is distributed between equal volumes of two immiscible solvents, water and dichloromethane, an equilibrium will be established.

$$
\mathrm{X}\left(\mathrm{H}_{2} \mathrm{O}\right) \rightleftharpoons \mathrm{X}\left(\mathrm{CH}_{2} \mathrm{Cl}_{2}\right) \quad \mathrm{K}=4
$$

In the diagrams below, the number of dots represents the relative distribution of $\mathbf{X}$ in the two solvents. Water is less dense than dichloromethane.
Which of the following shows the correct distribution of X between the two solvents at equilibrium?
A

C

B

D

30. A complexometric titration can be used to determine the concentration of

A calcium ions in milk
B chloride ions in sea water
C ethanoic acid in vinegar
D ethanol in wine.

## SECTION 2 - 70 marks

## Attempt ALL questions

1. Chlorine forms many compounds with other elements.
(a) The electronic configuration for a chlorine atom in its ground state is shown.

1 s

$2 s$

$2 p$

3s

$3 p$

Circle one electron in the above diagram that can be described by the following set of quantum numbers.

$$
n=2, l=1, m=-1, s=+\frac{1}{2}
$$

(An additional diagram, if required, can be found on page 28.)
(b) A compound of chlorine, boron trichloride, reacts with hydrogen to produce boron.

$$
\mathrm{BCl}_{3}(\mathrm{~g})+\frac{3}{2} \mathrm{H}_{2}(\mathrm{~g}) \rightarrow \mathrm{B}(\mathrm{~s})+3 \mathrm{HCl}(\mathrm{~g}) \quad \Delta H^{\circ}=127 \mathrm{~kJ} \mathrm{~mol}^{-1}
$$

The standard entropy change, $\Delta S^{\circ}$, is $79.4 \mathrm{~J} \mathrm{~K}^{-1} \mathrm{~mol}^{-1}$.
Calculate $\Delta G^{\circ}$, in $\mathrm{kJ} \mathrm{mol}^{-1}$, for this reaction at 298 K .

1. (continued)
(c) Another compound of chlorine, silver(I) chloride, forms an equilibrium mixture with excess chloride ions.

$$
\mathrm{AgCl}(\mathrm{~s})+\mathrm{Cl}^{-}(\mathrm{aq}) \rightleftharpoons \mathrm{AgCl}_{2}^{-}(\mathrm{aq}) \quad \Delta G^{\circ}=25 \cdot 6 \mathrm{~kJ} \mathrm{~mol}^{-1} \text { at } 298 \mathrm{~K}
$$

$\Delta G^{\circ}$ and the equilibrium constant, K , are related as shown.

$$
\Delta G^{\circ}=-2 \cdot 30 R T \log _{10} \mathrm{~K}
$$

$R=8.31 \times 10^{-3} \mathrm{~kJ} \mathrm{~K}^{-1} \mathrm{~mol}^{-1}$
$T=$ Temperature in Kelvin
Use this information to calculate the equilibrium constant, K , for this reaction.
2. Reaction kinetics can be used to determine the order and mechanism of chemical reactions.

A proposed mechanism for the reaction between hydrogen peroxide, $\mathrm{H}_{2} \mathrm{O}_{2}(\mathrm{aq})$, and iodide ions, $\mathrm{I}^{-}(\mathrm{aq})$, is shown below.

Step $1 \quad \mathrm{H}_{2} \mathrm{O}_{2}(\mathrm{aq})+\mathrm{I}^{-}(\mathrm{aq}) \rightarrow \mathrm{IO}^{-}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell)$ slow
Step $2 \mathrm{IO}^{-}(\mathrm{aq})+\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq}) \rightarrow \mathrm{HIO}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell)$ fast
Step $3 \mathrm{HIO}(\mathrm{aq})+\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})+\mathrm{I}^{-}(\mathrm{aq}) \rightarrow \mathrm{I}_{2}(\mathrm{aq})+2 \mathrm{H}_{2} \mathrm{O}(\ell)$ fast
(a) State what is meant by the order of a reaction.
(b) (i) Determine the overall order of reaction for the mechanism above.
(ii) Write the rate equation for this reaction.
(c) Write a balanced equation for the overall reaction.
3. Brass is a useful alloy of copper and zinc.

To determine the percentage of copper in a brass screw, a student dissolved the screw in $20 \mathrm{~cm}^{3}$ of concentrated nitric acid and made the resulting solution up to $250 \mathrm{~cm}^{3}$ in a volumetric flask.

Five standard solutions were prepared by diluting a $0 \cdot 10 \mathrm{moll}^{-1}$ stock solution of copper(II) nitrate with deionised water.
(a) One of the standard solutions had a concentration of $0.010 \mathrm{moll}^{-1}$.

Describe fully how this $0.010 \mathrm{moll}^{-1}$ solution should be prepared in a $50 \mathrm{~cm}^{3}$ volumetric flask from the $0 \cdot 10 \mathrm{moll}^{-1}$ stock solution.
(b) The colorimeter was fitted with a suitable filter and set to zero using a reference sample. The absorbance of the five standard solutions was determined and a calibration graph was drawn.

(i) Name the substance that should be used to set the colorimeter to zero.
3. (b) (continued)
(ii) The absorbance of the sample solution was $0 \cdot 71$. The sample solution was then diluted to decrease the concentration by half.
The absorbance of this diluted solution was then measured.
Explain why the sample solution was diluted.
(iii) The mass of the screw was 1.43 g .

The absorbance of the diluted solution was $0 \cdot 34$.
Calculate the percentage by mass of copper in the screw.
4. There are different definitions for acids and bases.
(a) One definition for acids and bases was proposed by Johannes Brønsted and Thomas Lowry.
(i) State the Brønsted-Lowry definition for a base.
(ii) A solution of hydrogen peroxide consists of two acid-conjugate base pairs.

$$
\mathrm{H}_{2} \mathrm{O}_{2}(\mathrm{aq})+\mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons \mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})+\mathrm{HO}_{2}^{-}(\mathrm{aq})
$$

Complete the table to identify one of the acid-conjugate base pairs.

| Acid |  |
| :--- | :--- |
| Conjugate base |  |

(b) Another definition for acids and bases was proposed by Gilbert Lewis. A Lewis acid is a substance that can accept a pair of non-bonding electrons. A Lewis base is a substance that can donate a pair of non-bonding electrons.

An example of a Lewis acid-base reaction is shown.

$$
\mathrm{B}(\mathrm{OH})_{3}(\mathrm{aq})+2 \mathrm{H}_{2} \mathrm{O}(\ell) \rightleftharpoons\left[\mathrm{B}(\mathrm{OH})_{4}\right]^{-}(\mathrm{aq})+\mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq})
$$

Explain why this is a Lewis acid-base reaction.
4. (continued)
(c) Acids can be classified as strong or weak. The table contains information about four acids.

| Name of acid | Formula | $\mathbf{K}_{\mathrm{a}}$ at 298 K |
| :---: | :---: | :---: |
| ethanoic | $\mathrm{CH}_{3} \mathrm{COOH}$ | $1.7 \times 10^{-5}$ |
| chloroethanoic | $\mathrm{CH}_{2} \mathrm{ClCOOH}$ | $1.6 \times 10^{-3}$ |
| dichloroethanoic | $\mathrm{CHCl}_{2} \mathrm{COOH}$ | $5 \cdot 0 \times 10^{-2}$ |
| trichloroethanoic | $\mathrm{CCl}_{3} \mathrm{COOH}$ | $2.3 \times 10^{-1}$ |

(i) Describe the relationship between the number of chlorine atoms in an acid molecule and the strength of the acid.
(ii) 1.89 g of chloroethanoic acid was dissolved in deionised water and the solution was made up to $250 \mathrm{~cm}^{3}$ in a volumetric flask.
(A) Calculate the concentration, in $\mathrm{moll}^{-1}$, of the chloroethanoic acid solution.
(B) Using your answer to (A) calculate the pH of the chloroethanoic acid solution.
4. (continued)
(d) The action of pH indicators and buffer solutions involves the chemistry of acids and bases.

Using your knowledge of chemistry, discuss the role of acids and bases in pH indicators and buffer solutions.
5. Electron transitions are responsible for some of the properties of metals such as sodium, zinc and strontium, and their compounds.
(a) The orange-yellow colour emitted by some fireworks is due to electron transitions in sodium.

The colour is produced when excited electrons return to their ground state.

State what caused the electrons to become excited.
(b) A solution containing the complex ion $\left[\mathrm{Zn}\left(\mathrm{H}_{2} \mathrm{O}\right)_{6}\right]^{2+}$ is colourless.
(i) State the name of this complex ion.
(ii) Electron transitions involving the d-subshell can give rise to colour in transition metal complexes.
Explain fully why a solution of the complex ion $\left[\mathrm{Zn}\left(\mathrm{H}_{2} \mathrm{O}\right)_{6}\right]^{2+}$ is colourless.
5. (continued)
(c) Photoelectron spectroscopy is a technique that provides information on electrons and energy levels in atoms. It uses electromagnetic radiation to eject electrons from an atom and measures the kinetic energy of these emitted electrons.
(i) A sample of strontium was exposed to electromagnetic radiation with a frequency of $3.08 \times 10^{17} \mathrm{~s}^{-1}$.
Calculate the energy, in J, of this electromagnetic radiation.
(ii) Binding energy, $E_{b}$, is the energy required to eject an electron from an atom. Binding energy is calculated in electron volts, eV, using the relationship

$$
E_{b}=E-E_{k}
$$

$E_{b}=$ binding energy
$E=$ energy of electromagnetic radiation
$E_{k}=$ kinetic energy of electron emitted
1 Joule $=6.24 \times 10^{18} \mathrm{eV}$
An electron was emitted with a kinetic energy, $E_{k}$, of 1254 eV .
Using your answer to part (i), calculate the binding energy, in eV, for this electron.
6. The concentration of ethanol in vodka can be determined by reacting the ethanol with excess acidified potassium dichromate solution.
$20.0 \mathrm{~cm}^{3}$ of vodka was transferred to a 1 litre volumetric flask and made up to the mark with deionised water. $1.0 \mathrm{~cm}^{3}$ of the diluted vodka was pipetted into a conical flask. $25.0 \mathrm{~cm}^{3}$ of $0.010 \mathrm{moll}^{-1}$ acidified potassium dichromate was added to the conical flask. The conical flask was then stoppered and warmed until the reaction was complete.
$3 \mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OH}(\mathrm{aq})+2 \mathrm{Cr}_{2} \mathrm{O}_{7}{ }^{2-}(\mathrm{aq})+16 \mathrm{H}^{+}(\mathrm{aq}) \rightarrow 3 \mathrm{CH}_{3} \mathrm{COOH}(\mathrm{aq})+4 \mathrm{Cr}^{3+}(\mathrm{aq})+11 \mathrm{H}_{2} \mathrm{O}(\ell)$
It was found that $1.65 \times 10^{-4}$ moles of dichromate ions were left unreacted.
(a) Calculate the concentration of ethanol, in $\mathrm{moll}^{-1}$, in the undiluted vodka.
(b) Explain why the acidified potassium dichromate was added in excess.
6. (continued)
(c) The experimentally determined value was higher than the actual concentration of ethanol in the vodka.

Other than apparatus uncertainties and transfer errors, suggest a reason why the experimentally determined concentration of ethanol was higher.
(d) Describe a suitable control experiment that could be used to validate this technique.
7. Carmine is a red pigment formed in a precipitation reaction.

(a) Carmine can be removed from the reaction mixture by filtration.

Suggest how the filtration could be carried out to ensure fast separation.
(b) The structure shown above contains both pi and sigma bonds.
(i) Explain how a sigma bond is formed.
(ii) A pi bond is formed as a result of $\mathrm{sp}^{2}$ hybridisation. Explain what is meant by $\mathrm{sp}^{2}$ hybridisation.
7. (continued)
(c) Carmine contains a conjugated system.

Explain fully how this conjugated system gives rise to the red colour of carmine.
(d) The use of carmine as a dye was largely abandoned in the nineteenth century.

One of the pigments used to replace carmine is alizarin.
Alizarin can be extracted from the root of a plant using methanol.

(i) Explain why methanol is a suitable solvent for this extraction.
7. (d) (continued)
(ii) The infrared spectrum of alizarin is shown below.

(A) Explain the effect infrared radiation has on the bonds within molecules and how this allows different functional groups to be identified.
(B) Circle a functional group in the structure below that is responsible for the peak at $3395 \mathrm{~cm}^{-1}$.
(An additional diagram, if required, can be found on page 28.)


Go to Answers

* X 713770120 *

7. (d) (ii) continued
(C) For the peak at $3395 \mathrm{~cm}^{-1}$ calculate
(I) the wavelength, in metres
(II) the energy, in $\mathrm{kJ} \mathrm{mol}^{-1}$, associated with this wavelength.
8. Benzene, cyclohexene and cyclohexane are cyclic hydrocarbons with six carbon atoms. Each hydrocarbon takes part in a wide variety of chemical reactions.
Using your knowledge of chemistry, discuss the reactions of these hydrocarbons.
9. Ephedrine can be used to prevent low blood pressure.

ephedrine
(a) Ephedrine can exist as different optical isomers due to the presence of chiral centres.
(i) Circle a chiral centre in the structure of ephedrine shown above.
(An additional diagram, if required, can be found on page 28.)
(ii) State what is meant by the term optical isomers.
10. (continued)
(b) The psychoactive substance cathinone has a similar structure to ephedrine and can be synthesised under certain conditions in two steps as shown.


1-phenylpropanone, $G F M=134 \mathrm{~g}$

(i) Suggest the type of chemical reaction taking place in Step 2 of the synthesis.
(ii) Calculate the mass of cathinone produced from 9.50 g of 1-phenylpropanone, assuming a percentage yield of $71 \cdot 8 \%$.
10. Compound $X$ can be added to petrol to make it burn more smoothly.

compound X
(a) Compound X belongs to a class of organic compounds.

Name this class of organic compounds.
(b) (i) Draw a skeletal structural formula for compound X.
(ii) Write the systematic name for compound X .
(c) Compound X can be produced by reacting 2-chloromethylpropane with methoxide ions.


2-chloromethylpropane
compound X
(i) Methoxide ions can be produced by reacting sodium with a reagent.

Name the reagent.
(ii) The reaction between 2-chloromethylpropane and methoxide ions proceeds by an $\mathrm{S}_{\mathrm{N}} 1$ mechanism involving a carbocation intermediate. Using structural formulae and curly arrow notation, outline the mechanism for this reaction.
(iii) Suggest why this reaction is more likely to proceed by an $\mathrm{S}_{\mathrm{N}} 1$ mechanism rather than an $\mathrm{S}_{\mathrm{N}} 2$ mechanism.
10. (continued)
(d) Compound X is not optically active.

Draw an isomer of compound X that is optically active.
(e) The low resolution ${ }^{1} \mathrm{H}$ NMR spectrum for compound X shown below is incomplete.

Complete the spectrum by drawing one line to show the correct chemical shift and relative intensity for the other hydrogen environment.
(An additional diagram, if required, can be found on page 29.)

[END OF QUESTION PAPER]

## 2019 Chemistry

## Advanced Higher

## Finalised Marking Instructions

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## Section 1

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

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## Section 2

| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 1. | (a) | Any one of the $2 p$ electrons | 1 | Only 1 electron to be circled |
|  | (b) | $103\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ <br> Partial marking $\Delta \mathrm{G}=\Delta \mathrm{H}-\mathrm{T} \Delta \mathrm{~S}$ <br> OR <br> correct substitution of values | 2 | 100/103•3/103•34 also acceptable <br> Unit not required but must be correct if given |
|  | (c) | $3.20 \times 10^{-5}$ <br> Partial marking $\begin{equation*} 25 \cdot 6=-2 \cdot 30 \times 8 \cdot 31 \times 10^{-3} \times 298 \times \log _{10} \mathrm{~K} \tag{1} \end{equation*}$ <br> OR $\begin{equation*} -4 \cdot 49464\left(=\log _{10} K\right) \tag{1} \end{equation*}$ <br> OR $\begin{equation*} \mathrm{K}=10^{-4 \cdot 49464} \tag{1} \end{equation*}$ <br> OR <br> A correctly calculated value of $K$ from an incorrectly calculated value of $\log _{10} \mathrm{~K}$ | 2 | $3 \cdot 2 / 3 \cdot 202 / 3 \cdot 2016 \times 10^{-5}$ also acceptable |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 2. | (a) |  | The number of species/molecules/ particles/ions/ moles of reactant(s) involved in the rate determining step/slowest step | 1 | The number of reactants in the rate determining step without reference to moles would not be awarded the mark |
|  | (b) | (i) | 2/2 ${ }^{\text {nd }}$ /second | 1 |  |
|  |  | (ii) | $\text { Rate }=k\left[\mathrm{H}_{2} \mathrm{O}_{2}\right]\left[\mathrm{I}^{-}\right]$ <br> OR $\text { Rate }=\mathrm{k}\left[\mathrm{H}_{2} \mathrm{O}_{2}\right]^{1}[\mathrm{I}]^{1}$ | 1 | State symbols not required but if given must be correct <br> K instead of k is not acceptable <br> Charge on I' must be shown <br> Square brackets must be used |
|  | (c) |  | $\begin{aligned} & \mathrm{H}_{2} \mathrm{O}_{2}(\mathrm{aq})+2 \mathrm{I}^{-}(\mathrm{aq})+2 \mathrm{H}_{3} \mathrm{O}^{+}(\mathrm{aq}) \rightarrow \\ & \mathrm{I}_{2}(\mathrm{aq})+4 \mathrm{H}_{2} \mathrm{O}(\mathrm{l}) \end{aligned}$ | 1 | State symbols not required but if given must be correct |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 3. | (a) |  | $\begin{equation*} 5 \mathrm{~cm}^{3} \tag{1} \end{equation*}$ <br> Correct procedure involving pipette/ burette and making up to the mark (with deionised/distilled water) | 2 |  |
|  | (b) | (i) | (Deionised/distilled) water | 1 |  |
|  |  | (ii) | The absorbance/value was outwith the calibration range/line <br> OR <br> To bring the absorbance/value to within the calibration range/line | 1 | Must make reference to the calibration range or line |
|  |  | (iii) | 71 (\%) <br> Partial marking <br> Up to 2 marks may be awarded for any two of the following <br> Concentration of $\mathrm{Cu}^{2+}=0.032$ <br> ( $\mathrm{mol} \mathrm{l}^{-1}$ ) <br> OR <br> Correct value from $\left[\mathrm{Cu}^{2+}\right] \times 0.25 \times 2 \times 63.5$ <br> OR <br> Correctly calculating a \% from a calculated mass of copper | 3 | 70/71.0/71.05 are also acceptable |

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| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :---: | :--- |
| 4. | (d) | This is an open ended question <br> 1 mark: The student has <br> demonstrated, at an appropriate <br> level, a limited understanding of the <br> chemistry involved. The student has <br> made some statement(s) that is/are <br> relevant to the situation, showing <br> that at least a little of the chemistry <br> within the context is understood. | $\mathbf{3}$ | Zero marks should be awarded if the <br> student has demonstrated an <br> understanding of the chemistry that <br> is below the appropriate level. |
| 2 marks: The student has <br> demonstrated, at an appropriate <br> level, a reasonable understanding of <br> the chemistry involved. The student <br> makes some statement(s) that is/are <br> relevant to the situation, showing <br> that the context is understood. | Zero marks should also be awarded if <br> the student merely restates the <br> chemistry given in the question. |  |  |  |
| 3 marks: The maximum available <br> mark would be awarded to a student <br> who has demonstrated, at an <br> appropriate level, a good <br> understanding, of the chemistry <br> involved. The student shows a good <br> comprehension of the chemistry of <br> the situation and has provided a <br> logically correct answer to the <br> question posed. This type of <br> response might include a statement <br> of the principles involved, a <br> relationship or an equation, and the <br> application of these to respond to <br> the context. This does not mean the <br> answer has to be what might be <br> termed an "excellent" answer or a <br> "complete" one. |  |  |  |  |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 5. | (a) |  | Heat/high temperature | 1 | Electrical discharge or light are not acceptable on their own but are not cancelling errors |
|  | (b) | (i) | Hexaaquazinc(II) | 1 | Must have brackets |
|  |  | (ii) | Full/complete d subshell/ 10 d electrons/3d ${ }^{10} /$ no d-d transitions possible <br> It does not absorb visible light OR It only absorbs ultraviolet/UV light | 2 | The first mark may not be awarded if the candidate implies that the d orbitals are not split or empty or that the energy gap between the d orbitals is too large <br> Any mention of HOMO-LUMO or emission is a cancelling error for the second mark |
|  | (c) | (i) | $2.04 \times 10^{-16}(\mathrm{~J})$ | 1 | $2 \cdot 0 / 2 \cdot 042 / 2 \cdot 0420 \times 10^{-16}$ are also acceptable <br> Unit not required but must be correct if given |
|  |  | (ii) | Method 1 $\begin{equation*} 19 \cdot 0(\mathrm{eV}) \tag{2} \end{equation*}$ <br> Partial marking <br> One mark can be awarded for: $E=2.04 \times 10^{-16} \times 6.24 \times 10^{18}=1272.9$ <br> OR <br> Correct subtraction involving incorrect values <br> Method 2 <br> $21 \cdot 0(\mathrm{eV})$ <br> Partial marking <br> One mark can be awarded for: correct subtraction of correct values in J $\begin{aligned} & 1254 \times 1.60 \times 10^{-19}=2.0064 \times 10^{-16}(\mathrm{~J}) \\ & E_{b}=2.04 \times 10^{-16}-2.0064 \times 10^{-16} \\ & E_{b}=3.36 \times 10^{-18}(\mathrm{~J}) \end{aligned}$ <br> OR <br> multiplication of a calculated $E_{b}$ in Joules by $6.24 \times 10^{18}$ | 2 | 19/18.96 also acceptable <br> Unit not required but must be correct if given <br> Method 2 <br> 21/20.97/20.966 also acceptable <br> Unit not required but must be correct if given |

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| Question |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: |
| 6. | (a) | $6 \cdot 4\left(\mathrm{~mol} \mathrm{l}^{-1}\right)$ <br> Partial marking <br> Up to 2 marks may be awarded for any two of the following <br> $8.5 \times 10^{-5}\left(\mathrm{~mol} \mathrm{Cr}_{2} \mathrm{O}_{7}^{2-}\right.$ reacted with $\mathrm{C}_{2} \mathrm{H}_{5} \mathrm{OH}$ ) <br> OR <br> Correct subtraction of $1.65 \times 10^{-4}$ from an incorrectly calculated number of moles of $\mathrm{Cr}_{2} \mathrm{O}_{7}{ }^{2-}$ <br> OR <br> Use of 3:2 mole ratio on an incorrect number of moles of $\mathrm{Cr}_{2} \mathrm{O}_{7}{ }^{2-}$ <br> OR <br> Multiplication of an incorrect number of moles by 1000 and dividing by 0.02 / multiplication by 50,000 | 3 | 6/6•38/6•375 also acceptable <br> Unit not required but if given must be correct. |
|  | (b) | To ensure all the ethanol reacted. | 1 | To ensure the reaction goes to completion is unacceptable on its own <br> Ethanol is the limiting reactant is unacceptable on its own <br> Vodka instead of ethanol is unacceptable |
|  | (c) | Other ingredients/impurities in the vodka may be reacting with dichromate <br> OR <br> Concentration of dichromate was greater (than $0.010 \mathrm{~mol} \mathrm{l}^{-1}$ ) | 1 | Different dichromate concentration is unacceptable on its own |
|  | (d) | Use a known concentration/standard solution of ethanol <br> OR <br> Use pure ethanol | 1 |  |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (a) |  | Under vacuum/suction/reduced pressure <br> OR <br> Acceptable diagram indicating vacuum/suction/reduced pressure | 1 | A mark should not be awarded for "use a Buchner funnel/flask" without further explanation |
|  | (b) | (i) | End on overlap of (two atomic) orbitals <br> OR <br> Acceptable labelled diagram | 1 | Any mention of overlap of molecular orbitals is a cancelling error. |
|  |  | (ii) | Mixing an s (atomic) orbital with two $p$ (atomic) orbitals | 1 | Any mention of forming molecular orbitals is a cancelling error. |
|  | (c) |  | Electrons promoted/move from HOMO to LUMO <br> The complementary colour(s) (to red) is absorbed <br> OR <br> Blue/green light is absorbed | 2 | Direction of electron transition must be given <br> Any mention of emission/giving out or dropping energy levels is a cancelling error for the second mark |
|  | (d) | (i) | Similar polarities/both polar/similar intermolecular forces <br> OR <br> Forms hydrogen bonds with alizarin OR <br> Does not react with alizarin OR <br> Volatile/low boiling point/ evaporates easily <br> OR <br> Dissolves alizarin but not other substances (in the root) | 1 | Both non-polar is not acceptable <br> Alizarin dissolves in methanol is not a sufficiently detailed response on its own |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 7. | (d) | (ii) <br> (A) | Vibrate/bend/stretch <br> Different bonds/functional groups absorb at different wavenumber/ wavelength/frequency/energy | 2 |  |
|  |  | (ii) <br> (B) | Circle one/both OH group(s) | 1 |  |
|  |  | (ii) <br> (C) <br> (I) | $2.946 \times 10^{-6}(\mathrm{~m})$ | 1 | 2.95/2.9455/2.94551 $\times 10^{-6}$ are also acceptable <br> Unit not required but if given must be correct |
|  |  | (ii) <br> (C) <br> (II) | $40 \cdot 6\left(\mathrm{~kJ} \mathrm{~mol}^{-1}\right)$ <br> Partial marking <br> One partial mark can be awarded for correct equations $-c=f \lambda$ and $E=L h f$ OR substitution into the correct equations | 2 | 41/40•64/40•644 also acceptable <br> Unit not required but must be correct if given <br> Allow follow through |

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| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :---: | :--- |
| 8. |  | This is an open ended question <br> 1 mark: The student has <br> demonstrated, at an appropriate <br> level, a limited understanding of the <br> chemistry involved. The student has <br> made some statement(s) that is/are <br> relevant to the situation, showing <br> that at least a little of the chemistry <br> within the context is understood. | $\mathbf{3}$ | Zero marks should be awarded if the <br> student has demonstrated an <br> understanding of the chemistry that <br> is below the appropriate level. |
| 2 marks: The student has <br> demonstrated, at an appropriate <br> level, a reasonable understanding of <br> the chemistry involved. The student <br> makes some statement(s) that is/are <br> relevant to the situation, showing <br> that the context is understood. | Zero marks should also be awarded if <br> the student merely restates the <br> chemistry given in the question. |  |  |  |
| 3 marks: The maximum available <br> mark would be awarded to a student <br> who has demonstrated, at an <br> appropriate level, a good <br> understanding, of the chemistry <br> involved. The student shows a good <br> comprehension of the chemistry of <br> the situation and has provided a <br> logically correct answer to the <br> question posed. This type of <br> response might include a statement <br> of the principles involved, a <br> relationship or an equation, and the <br> application of these to respond to <br> the context. This does not mean the <br> answer has to be what might be <br> termed an "excellent" answer or a <br> "complete" one. |  |  |  |  |

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| Question |  | Expected response |  | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :---: | :--- |
| 9. | (a) | (i) |  |  |  |

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| Question |  |  | Expected response | Max mark | Additional guidance |
| :---: | :---: | :---: | :---: | :---: | :---: |
| 10. | (a) |  | Ethers | 1 |  |
|  | (b) | (i) | Skeletal formula of compound $X$ | 1 |  |
|  |  | (ii) | 2-methoxy-2-methylpropane <br> 2-methoxymethylpropane <br> 2-methyl-2-methoxypropane <br> Methyl-2-methoxypropane | 1 |  |
|  | (c) | (i) | Methanol/ $/ \mathrm{CH}_{3} \mathrm{OH} / \mathrm{CH}_{4} \mathrm{O}$ | 1 |  |
|  |  | (ii) | 1 mark for intermediate and one ma | 2 $- \text { - } \mathrm{CH}$  <br> for bo | An incorrectly drawn methoxide ion is a cancelling error for the intermediate mark. <br> The final product is not required. <br> An $\mathrm{S}_{\mathrm{N}} 2$ mechanism is awarded zero marks. <br> Zero marks are awarded for a general mechanism. <br> curly arrows being correct |
|  |  | (iii) | Formation of a stable (tertiary) carbocation/inductive stabilisation OR <br> steric hindrance or description | 1 |  |

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| Question |  | Expected response | Max <br> mark | Additional guidance |
| :--- | :--- | :--- | :--- | :---: | :---: |
| 10. | (d) | Any correct structure that is an <br> isomer and has a chiral centre <br> For example, <br> pentan-2-ol/3-methylbutan-2-ol/ <br> 2-methylbutan-1-ol/ <br> 2-methoxybutane | 1 |  |
| (e) | One line at 1•5-0•9 <br> Relative intensity 9 | (1) | 2 |  |

[END OF MARKING INSTRUCTIONS]

