**CHEMISTRY (PRINCIPAL)** **9791/01**

Paper 1 Multiple Choice **May/June 2019**

**1 hour**

Additional Materials: Multiple Choice Answer Sheet
Soft clean eraser
Soft pencil (type B or HB is recommended)
Data Booklet

## READ THESE INSTRUCTIONS FIRST

Write in soft pencil.

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

Write your name, centre number and candidate number on the Answer Sheet in the spaces provided unless this has been done for you.

DO **NOT** WRITE IN ANY BARCODES.

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

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

**Read the instructions on the Answer Sheet very carefully.**

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

Any working should be done in this booklet.

Electronic calculators may be used.

This document consists of **15** printed pages and **1** blank page.

Cambridge Assessment
International Education

**[Turn over**

1   Which word describes one of the main stages of heterogeneous catalysis?

   **A**   acceleration

   **B**   adsorption

   **C**   distillation

   **D**   ionisation

2   Which hydrocarbon forms two monobromo compounds that are structural isomers of each other?

   **A**   2,2-dimethylpropane

   **B**   2-methylpropane

   **C**   cyclobutane

   **D**   ethane

3   What is the most likely physical property represented on the graph?



relative mass
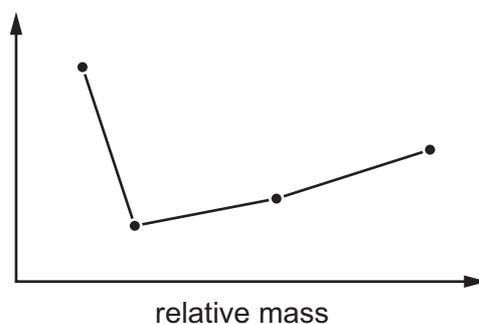
   **A**   boiling point of HF, HC$l$, HBr and HI

   **B**   density of $F_2$(g), C$l_2$(g), $Br_2$(g) and $I_2$(g)

   **C**   first ionisation energy of F(g), C$l$(g), Br(g) and I(g)

   **D**   volume of one mole of HF(g), HC$l$(g), HBr(g) and HI(g) at r.t.p.

4   Two elements that have very similar electronegativity values chemically combine.

   The compound they form is plotted on a van Arkel triangle.

   Which statement about the compound must be correct?

   **A**   The compound is a semiconductor.

   **B**   The covalent character is high.

   **C**   The ionic character is low.

   **D**   The metallic character is low.

**5** The type of reaction shown is known as decarboxylation.

$$RCONH_2 + 2KOH + Br_2 \rightarrow RNH_2 + CO_2 + H_2O + 2KBr$$

Which amide could be used to prepare 1,2-diaminoethane by this method?

**A** $CH_3CONH_2$

**B** $H_2NCOCH_2CONH_2$

**C** $H_2NCOCH(CH_3)CONH_2$

**D** $H_2NCOCH_2CH_2CONH_2$

**6** In the ideal gas equation, $pV = nRT$, the molar gas constant, $R$, has the value $8.31\,J\,K^{-1}\,mol^{-1}$.

In which units must $p$ and $V$ be expressed to be consistent with this value of $R$?

|   | $p$ | $V$ |
|---|-----|-----|
| **A** | atm | $dm^3$ |
| **B** | atm | $m^3$ |
| **C** | Pa | $dm^3$ |
| **D** | Pa | $m^3$ |

**7** Which row gives a correct description for molecules of nitrogen and white phosphorus?

|   | bond | | formula | | polarity | |
|---|---|---|---|---|---|---|
|   | nitrogen | phosphorus | nitrogen | phosphorus | nitrogen | phosphorus |
| **A** | $\sigma$ and $\pi$ | $\sigma$ only | $N_2$ | $P_4$ | non-polar | non-polar |
| **B** | $\sigma$ and $\pi$ | $\pi$ only | $N_2$ | $P_4$ | non-polar | polar |
| **C** | $\sigma$ only | $\sigma$ only | $N_2$ | $P_2$ | polar | non-polar |
| **D** | $\sigma$ only | $\pi$ only | $N_2$ | $P_2$ | polar | non-polar |

**8** The apparatus shows an unsuccessful attempt to prepare and collect dry sulfur dioxide.
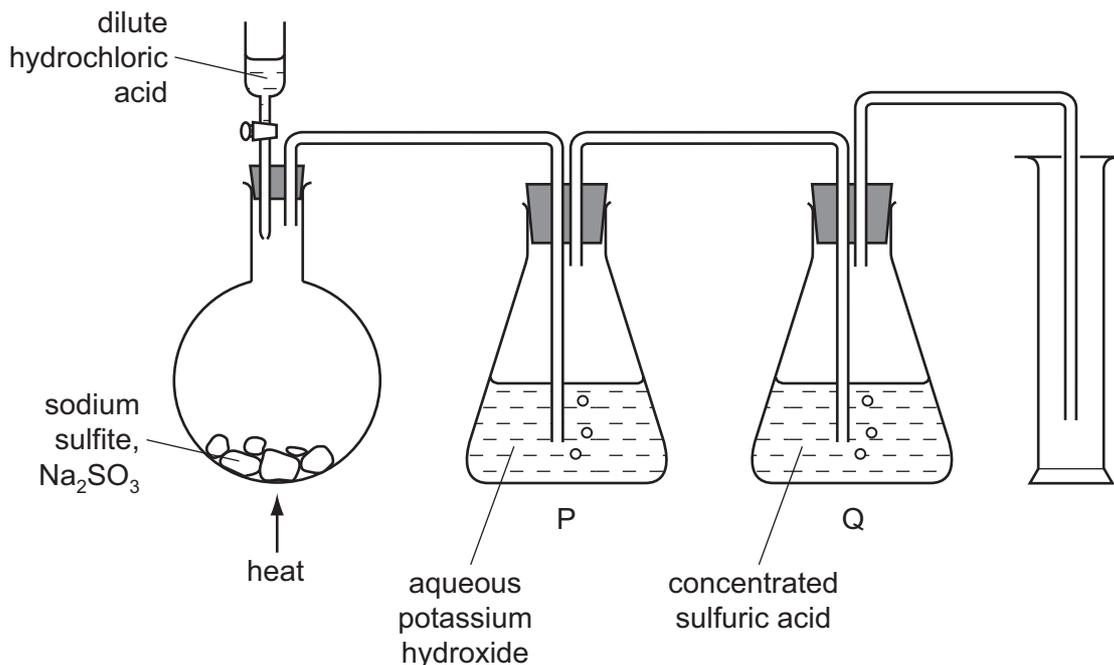


Which change would make the experiment successful?

**A** omitting flask P

**B** omitting flask Q

**C** using dilute nitric acid instead of dilute hydrochloric acid

**D** using sodium sulfate instead of sodium sulfite

**9** Methane is a greenhouse gas but is destroyed in the troposphere by the action of hydroxyl radicals.

$$•OH \ + \ CH_4 \ \rightarrow \ •CH_3 \ + \ H_2O$$

Which statement about this reaction is correct?

**A** The reaction involves heterolytic fission and $\sigma$ bond formation.

**B** The reaction involves homolytic fission and $\sigma$ bond formation.

**C** The reaction involves homolytic fission and $\pi$ bond formation.

**D** The total number of electrons in the two reacting species is 20.

**10** Four elements, W, X, Y and Z, are in the potassium to krypton period with consecutive atomic numbers. The table shows the number of unpaired electrons in each atom in its ground state.

| element | W | X | Y | Z |
|---|---|---|---|---|
| unpaired electrons | 2 | 1 | 0 | 1 |

In which group of the Periodic Table is element W?

**A** 4 **B** 10 **C** 14 **D** 15

**11** Which compound is a major renewable feedstock for the chemical industry?

**A** ethane

**B** ethanol

**C** propane

**D** propan-1-ol

**12** Barbituric acid, the basis for synthesising barbiturates, can be made by the reaction shown.



urea     malonic acid     barbituric acid
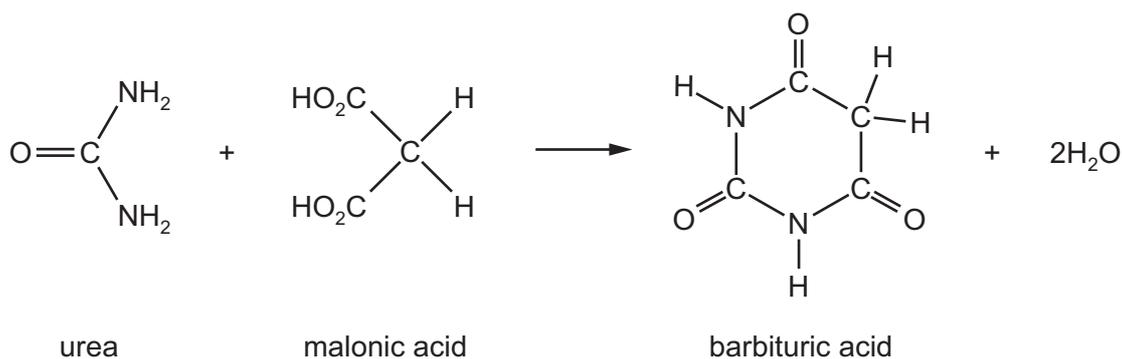
In this reaction, how many carbon atoms change their functional group level?

**A** 0 **B** 1 **C** 2 **D** 3

**13** 2-bromomethylpropane, $(CH_3)_3CBr$, reacts with aqueous sodium hydroxide to form methylpropan-2-ol, $(CH_3)_3COH$, and NaBr.

Which statement about the mechanism of this reaction is correct?

**A** An intermediate is formed in which there is only one bond angle around the central carbon.

**B** The first step involves attack by a nucleophile on a $\delta+$ carbon atom.

**C** The first step involves homolytic bond fission.

**D** The second step involves attack by an $OH^-$ ion on an anionic intermediate.

**14** When silicon tetrachloride is added to water, which description is correct?

**A** $SiCl_4$ dissolves to give a neutral solution.

**B** $SiCl_4$ reacts to give an acidic solution and a precipitate.

**C** $SiCl_4$ reacts to give an acidic solution only.

**D** $SiCl_4$ reacts to give a neutral solution and a precipitate.

**15** X is an element in Period 3. X forms an oxide and a chloride.

Two test-tubes are half-filled with water containing a little universal indicator. A small amount of the oxide of X is added to the first test-tube. A small amount of the chloride of X is added to the second test-tube.

The final colour in both test-tubes is the same.

What could element X be?

**A** aluminium

**B** magnesium

**C** phosphorus

**D** sodium

**16** Two strained polycyclic hydrocarbons of interest to chemists, called 'windowpane' and 'broken windowpane', are shown in skeletal form.
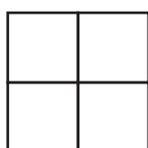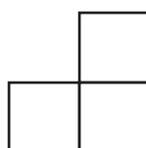


windowpane          broken windowpane

Which row gives the number of carbon environments and molecular formula for each molecule?

| | windowpane | | broken windowpane | |
|---|---|---|---|---|
| | C environments | molecular formula | C environments | molecular formula |
| **A** | 3 | $C_9H_8$ | 4 | $C_8H_{10}$ |
| **B** | 3 | $C_9H_{12}$ | 5 | $C_8H_{12}$ |
| **C** | 5 | $C_9H_{12}$ | 5 | $C_8H_{10}$ |
| **D** | 9 | $C_9H_8$ | 8 | $C_8H_{12}$ |

**17** Three reactions are shown.

    1   $(CH_3)_2C=CHCH_3 + HBr(g) \rightarrow (CH_3)_2CBrCH_2CH_3$

    2   $(CH_3)_2C=CHCH_3 + Br_2(l) \rightarrow (CH_3)_2CBrCHBrCH_3$

    3   $(CH_3)_2CBrCH_2CH_3 + OH^-(aq) \rightarrow (CH_3)_2C(OH)CH_2CH_3 + Br^-(aq)$
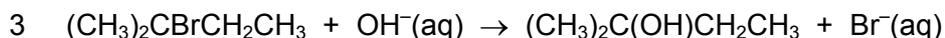
In which of the reactions is the 2-methylbut-2-yl cation, $(CH_3)_2C^+CH_2CH_3$, an intermediate?

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

**18** Two electrolysis cells are set up such that the same current flows for the same time through each of them. Cell X contains molten aluminium oxide, $Al_2O_3$, and cell Y contains molten sodium chloride, $NaCl$.



molten $Al_2O_3$        molten $NaCl$

     X        Y
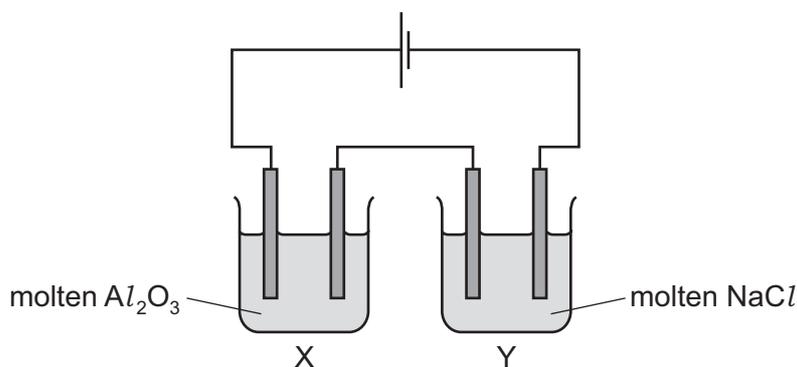
What is the simplest whole number ratio, cell X : cell Y, of the masses deposited at the cathode of each cell?

**A**  $1:3$        **B**  $9:23$        **C**  $27:23$        **D**  $81:23$

**19** In which reaction will the position of equilibrium shift to the left with an increase in temperature but to the right with an increase in pressure?

**A**  $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$   $\Delta H^{\ominus} = +206.1\,kJ\,mol^{-1}$

**B**  $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$   $\Delta H^{\ominus} = -41.2\,kJ\,mol^{-1}$

**C**  $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$         $\Delta H^{\ominus} = -114\,kJ\,mol^{-1}$

**D**  $N_2O_4(g) \rightleftharpoons 2NO_2(g)$             $\Delta H^{\ominus} = +57\,kJ\,mol^{-1}$
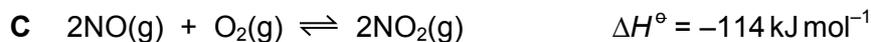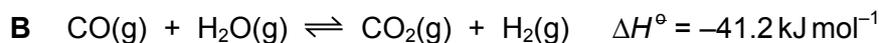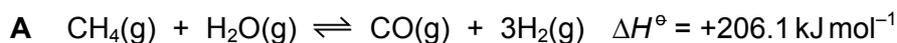
20 At a particular temperature, the value of $K_c$ for the equilibrium shown is equal to 0.36.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$
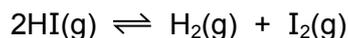
Which row of data is consistent with this value?

|   | [HI] / mol dm$^{-3}$ | [H$_2$] / mol dm$^{-3}$ | [I$_2$] / mol dm$^{-3}$ |
|---|---|---|---|
| **A** | 0.5 | 0.36 | 1.0 |
| **B** | 1.0 | 0.18 | 0.18 |
| **C** | 2.0 | 0.72 | 1.0 |
| **D** | 2.0 | 1.2 | 1.2 |

21 Which aqueous solution would have the lowest pH?

**A**  3.65 g dm$^{-3}$ HC$l$

**B**  4.41 g dm$^{-3}$ HNO$_3$

**C**  5.00 g dm$^{-3}$ C$_2$H$_5$OH

**D**  6.00 g dm$^{-3}$ CH$_3$COOH

22 A conical flask contains acidified Fe$^{2+}$(aq). KMnO$_4$(aq) is added with stirring until present in large excess.

Which colour changes are seen in the conical flask?

**A**  pale green $\rightarrow$ yellow $\rightarrow$ pink $\rightarrow$ purple

**B**  purple $\rightarrow$ pink $\rightarrow$ colourless

**C**  purple $\rightarrow$ pink $\rightarrow$ yellow $\rightarrow$ green

**D**  yellow $\rightarrow$ pale green $\rightarrow$ pink $\rightarrow$ purple

23 A mixture of solids is treated with an excess of dilute hydrochloric acid.

A colourless gas is evolved and a white precipitate forms.

What are the solids in the mixture?

**A**  calcium carbonate and magnesium hydroxide

**B**  calcium carbonate and magnesium nitrate

**C**  lead nitrate and calcium hydroxide

**D**  silver nitrate and magnesium carbonate

**24** In which list do the oxidation states of the metals in the four complex ions increase from left to right?

**A** $[OsO_4F_2]^{2-} \rightarrow [ReOCl_4]^- \rightarrow [IrO_4]^+ \rightarrow [UO_2]^{2+}$

**B** $[ReOCl_4]^- \rightarrow [OsO_4F_2]^{2-} \rightarrow [UO_2]^{2+} \rightarrow [IrO_4]^+$

**C** $[ReOCl_4]^- \rightarrow [UO_2]^{2+} \rightarrow [OsO_4F_2]^{2-} \rightarrow [IrO_4]^+$

**D** $[UO_2]^{2+} \rightarrow [IrO_4]^+ \rightarrow [ReOCl_4]^- \rightarrow [OsO_4F_2]^{2-}$

**25** The two isomers of $N_2F_2$ have the structures shown.
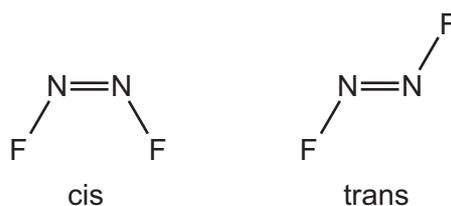


cis                    trans

What is the number of signals in the $^{19}F$ NMR spectrum of each structure?

|   | cis | trans |
|---|-----|-------|
| **A** | 1 | 1 |
| **B** | 1 | 2 |
| **C** | 2 | 1 |
| **D** | 2 | 2 |

**26** The ester $C_6H_5COOCH_2CH_2CH_3$ was hydrolysed using aqueous sodium hydroxide. Subsequent addition of excess acid produced a white precipitate.

What was the precipitate?

**A** $CH_3CH_2CH_2ONa$

**B** $CH_3CH_2CH_2OH$

**C** $C_6H_5COONa$

**D** $C_6H_5COOH$

27 Reacting the unsaturated dicarboxylic acid **X** with hydrogen over a nickel catalyst produces compound **Y**.
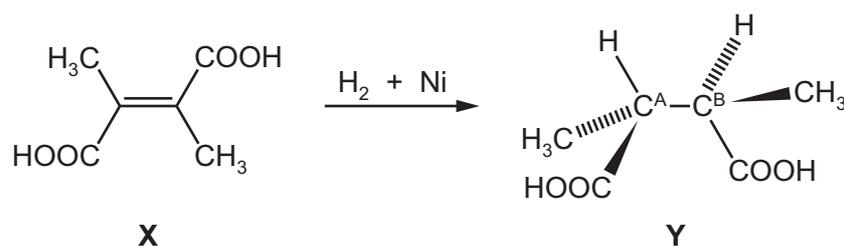


What are the correct *R*/*S* assignments for carbon atoms $C^A$ and $C^B$ in compound **Y**?

|   | $C^A$ | $C^B$ |
|---|-------|-------|
| **A** | *R* | *R* |
| **B** | *R* | *S* |
| **C** | *S* | *R* |
| **D** | *S* | *S* |

28 The diagram shows the structure of glycerol.
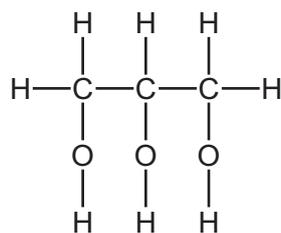


How many hydrogen environments are there in glycerol and how many of these environments contain labile protons?

|   | hydrogen environments | labile hydrogen environments |
|---|-----------------------|------------------------------|
| **A** | 2 | 1 |
| **B** | 4 | 2 |
| **C** | 4 | 3 |
| **D** | 6 | 3 |

**29** Some data is given in the table.

| enthalpy | value / kJ mol$^{-1}$ |
|---|---|
| standard enthalpy of formation of $SF_6$, $\Delta_fH^{\ominus}$ ($SF_6$) | −1100 |
| standard enthalpy of atomisation of S, $\Delta_{at}H^{\ominus}$ (S) | 223 |
| F–F bond enthalpy | 158 |

What is the average S–F bond enthalpy in $SF_6$(g)?

**A** 247 kJ mol$^{-1}$ **B** 300 kJ mol$^{-1}$ **C** 379 kJ mol$^{-1}$ **D** 1797 kJ mol$^{-1}$

**30** Hot concentrated nitric acid, $HNO_3$, is a powerful oxidising agent.

In its reaction with carbon, the oxidation number of carbon increases by 4 and the oxidation number of nitrogen decreases by 1.

How many moles of nitric acid are needed to oxidise one mole of carbon in this reaction?

**A** 1 **B** 2 **C** 3 **D** 4

**31** Compound P decomposes to form substances Q and R. The reaction reaches equilibrium.

Under certain conditions, $n$ moles of P are placed in a sealed vessel. When equilibrium is reached the vessel contains $x$ moles of Q.

The total number of moles of P, Q and R in the vessel at equilibrium is:

$$\left[n + \frac{3x}{2}\right]$$

What is the balanced chemical equation for the decomposition of P?

**A** P $\rightleftharpoons$ Q + 3R

**B** P $\rightleftharpoons$ 2Q + 3R

**C** 2P $\rightleftharpoons$ Q + 3R

**D** 2P $\rightleftharpoons$ 2Q + 3R

**32** Aspirin can be prepared by either of the two reactions shown.

reaction 1



+ (CH$_3$CO)$_2$O $\longrightarrow$



+ CH$_3$COOH

aspirin

reaction 2



+ CH$_3$COC$l$ $\longrightarrow$



+ HC$l$
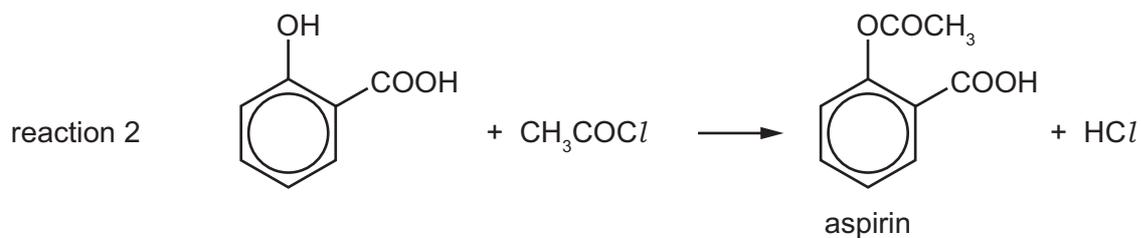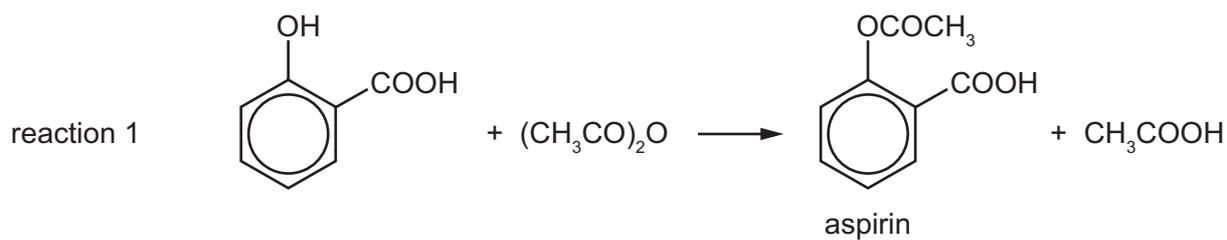
aspirin

Assuming aspirin is the only utilised product, which statement is correct?

**A** Adding a catalyst to either reaction will increase its atom economy.

**B** Reaction 1 has a higher atom economy than reaction 2.

**C** Reaction 2 has a higher atom economy than reaction 1.

**D** Since both reactions have one common starting material, there is no difference in atom economy.

**33** A solution of chlorocyclohexane and sodium hydroxide is refluxed.

The organic product of this reaction has the infra-red spectrum shown.
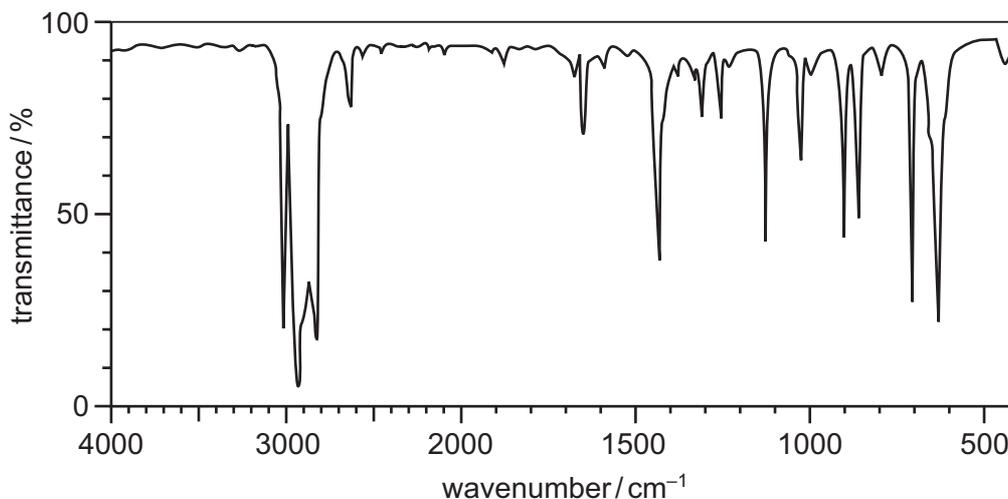


Which statement about this reaction is correct?

**A** Cyclohexanol is formed in an elimination reaction.

**B** Cyclohexanol is formed in a hydrolysis reaction.

**C** Cyclohexene is formed in an elimination reaction.

**D** Cyclohexene is formed in a hydrolysis reaction.

**34** The solubility product, $K_{sp}$, of silver sulfate, $Ag_2SO_4$, at 25 °C is $1.6 \times 10^{-5}$.

What is the solubility of silver sulfate at this temperature?

**A** $0.00499 \, g \, dm^{-3}$

**B** $0.0159 \, g \, dm^{-3}$

**C** $1.25 \, g \, dm^{-3}$

**D** $4.95 \, g \, dm^{-3}$

**35** A solution contains a complex of $Zn^{2+}$ ions.

Which row describes the solution and the reason for the observation?

|   | observation | reason |
|---|---|---|
| **A** | The solution is coloured. | An electron is promoted from a lower energy 3d orbital in $Zn^{2+}$ to a higher energy 3d orbital. |
| **B** | The solution is coloured. | The d-orbitals split in $Zn^{2+}$ and no electron promotion occurs. |
| **C** | The solution is colourless. | The d-orbitals split in $Zn^{2+}$ and each 3d orbital is fully occupied. |
| **D** | The solution is colourless. | The d-orbitals do not split in $Zn^{2+}$ because Zn is not a transition metal. |

**36** This question is about carboxylic acids.

Which statement is correct?

**A** Carboxylic acids can be reduced by $NaBH_4$ in aqueous methanol.

**B** Ethanoic acid can be oxidised by acidified potassium dichromate solution.

**C** Ethanoic acid can be synthesised from the Grignard reagent ethyl magnesium bromide and carbon dioxide.

**D** Synthesis of a carboxylic acid from Grignard reagents and carbon dioxide involves the carbon atom of the carbon dioxide moving down a functional group level.

**37** Which compound will give a ketone on hydrolysis?

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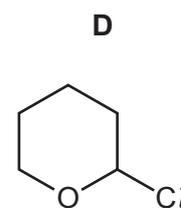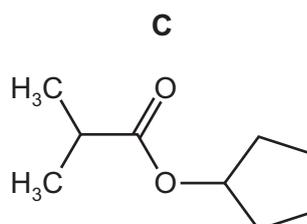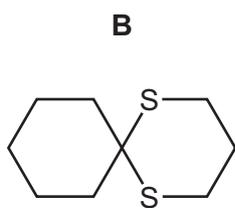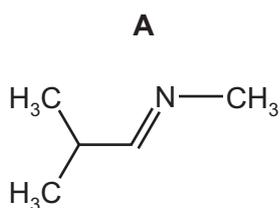


**38** When steam is condensed, $44\,kJ\,mol^{-1}$ of heat is given off.

What is the entropy change when 72 g of steam is condensed at $100\,°C$ and 1 atm pressure?

**A** $-472\,J\,K^{-1}$       **B** $-118\,J\,K^{-1}$       **C** $+118\,J\,K^{-1}$       **D** $+472\,J\,K^{-1}$

**39** Ethanedioic acid $(COOH)_2$ is a poison found in rhubarb leaves. It can be estimated by titration with a standard solution of potassium manganate$(VII)$.

Consider the two half-equations shown.

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

$$(COOH)_2(aq) \rightarrow 2CO_2(g) + 2H^+ + 2e^-$$

What is the volume of $0.0200\,mol\,dm^{-3}$ $MnO_4^-(aq)$ that will react with $25.0\,cm^3$ of $0.0400\,mol\,dm^{-3}$ ethanedioic acid?

**A**   $12.5\,cm^3$          **B**   $20.0\,cm^3$          **C**   $50.0\,cm^3$          **D**   $125\,cm^3$

**40** The $^1H$ NMR spectrum of which compound will show both a quartet and a doublet (possibly together with other peaks)?

**A**   $(CH_3)_2CHCl$

**B**   $CH_3CH_2CH_2Cl$

**C**   $CH_3CCl_2CHClCH_3$

**D**   $CH_3CH_2CHCl_2$

# BLANK PAGE