RAFFLES INSTITUTION
2022 YEAR 6 PRELIMINARY EXAMINATION

Higher 2

CHEMISTRY 9729/01

Paper 1 Multiple Choice **22 September 2022**

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number in the spaces provided on the Answer Sheet.

There are **thirty** questions in 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 rough working should be done in the question booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **14** printed pages.

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

Which statement is correct?

A 2 mol of $(NH_4)_2Fe(SO_4)_2$ has the same number of ions as 4 mol of $K_2Cr_2O_7$.

B 46 g of nitrogen dioxide gas contains the same number of molecules as 14 g of nitrogen gas.

C The number of electrons in 1 mol of nitrogen gas is the same as that in 1 mol of carbon monoxide gas.

D The number of atoms in a 5 dm^3 sample of oxygen gas is half that of a 10 dm^3 sample of argon gas at the same temperature and pressure.

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

Bronze is an alloy of copper and tin. The following information is obtained for a sample of bronze.

mass number	63	65	118
% composition	d	88 – d	12

Naturally occurring copper contains only two isotopes, ^{63}Cu and ^{65}Cu.

Given the ratio of ^{63}Cu and ^{65}Cu in naturally occurring copper is the same as that in bronze, what is the value of d?

A 22 **B** 25 **C** 66 **D** 75

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

Which statements regarding the ions $^{30}Si^{4+}$, $^{31}P^{3-}$ and $^{32}S^{2-}$ are correct?

1 They contain the same number of neutrons.

2 They have the same electronic configuration.

3 Their ionic radii increase in the order $^{30}Si^{4+} < {}^{31}P^{3-} < {}^{32}S^{2-}$.

A 1 only

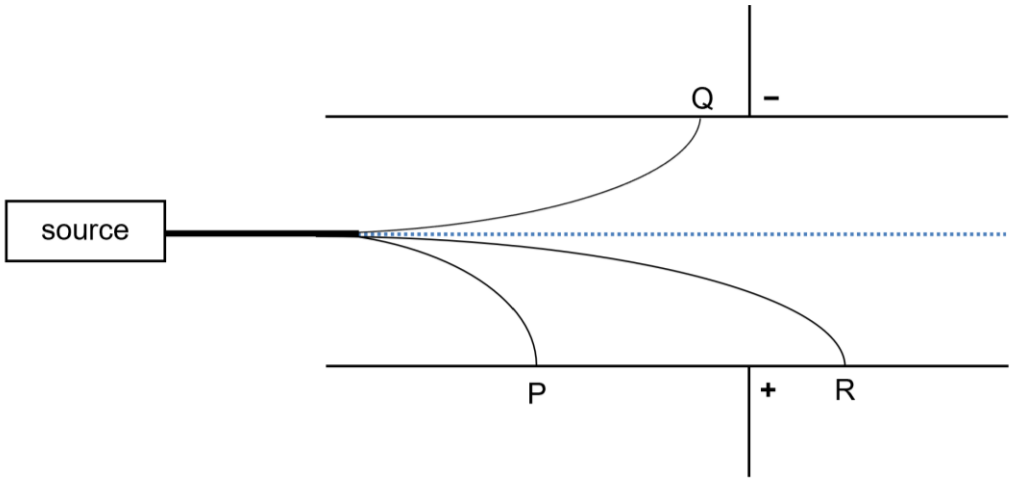
B 1 and 2

C 1 and 3

D 2 and 3

4 A beam containing a mixture of three ions, P, Q and R, approaches an electric field with oppositely charged plates at the same velocity.

The identities of the three ions could be $^{11}C^{3+}$, $^{15}O^{2+}$, $^{7}Li^{2-}$ and $^{15}N^{4-}$.



Which ion is Q?

A $^{11}C^{3+}$ **B** $^{15}O^{2+}$ **C** $^{7}Li^{2-}$ **D** $^{15}N^{4-}$

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

The first four ionisation energies, IE, of four Period 5 elements, indium, tin, antimony and tellurium are shown in the table below.

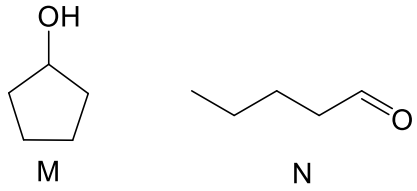
Which element is indium?

	first IE / kJ mol^{-1}	second IE / kJ mol^{-1}	third IE / kJ mol^{-1}	fourth IE / kJ mol^{-1}
A	558	1830	2704	5210
B	709	1411	2943	3930
C	834	1594	2440	4260
D	869	1790	2698	3610

6 In which row does G have a smaller overall dipole moment than H?

	G	H
A	COS	CS_2
B	PCl_3	PF_3
C	IF	BrCl
D	XeF_4	PCl_5

7 The structures of M and N are as shown.



M N

Which statements are correct?

1 M has a lower volatility than N.
2 M and N are constitutional isomers.
3 M and N have the same number of σ bonds.

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

8 Which compound has the greatest covalent character?

A MgO
B MgS
C CaO
D CaS

9 A 1 m^3 vessel containing 20 kPa of helium was connected to a 2 m^3 vessel containing 10 kPa of neon and the gases were allowed to mix at a constant temperature.

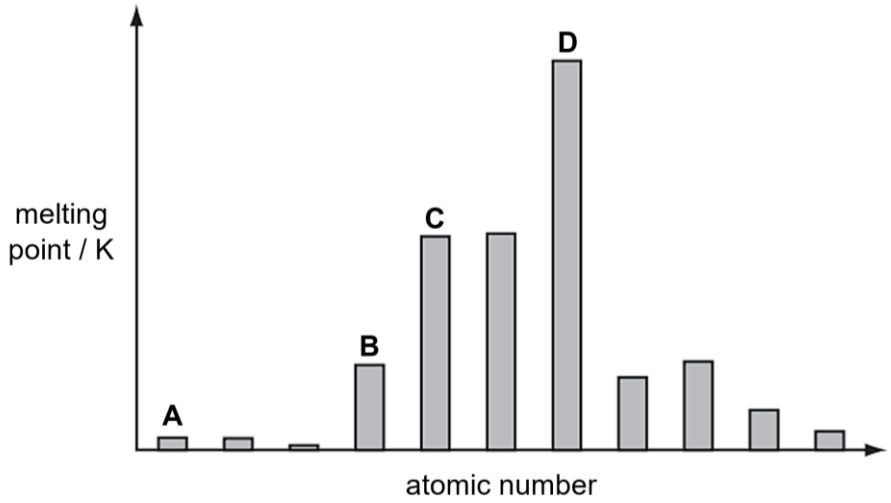
The two vessels were then cooled, and the temperature of the system decreased. The partial pressures of helium and neon were measured to be **U** kPa and **V** kPa respectively.

What could be the values of **U** and **V**?

	U	**V**
A	10	5
B	7.5	7.5
C	8	4
D	6	6

10 The bar chart shows the melting points of a series of consecutive elements arranged in order of increasing atomic number. The elements sodium to chlorine form part of this series.

Which bar represents sodium?



11 Which statement about the element astatine is correct?

A Silver astatide is insoluble in aqueous ammonia.

B Astatine is a liquid at room temperature and pressure.

C The bond energy of hydrogen astatide is larger than that of hydrogen iodide.

D Astatine is not a product of the reaction between sodium astatide and bromine.

12 Cyclohexane, C_6H_{12}, is prepared industrially by the hydrogenation of benzene as shown in the equation below.

$$C_6H_6(l) + 3H_2(g) \longrightarrow C_6H_{12}(l) \qquad \Delta H_r^{\ominus}$$

Using the data in the table, what is the standard enthalpy change, $\Delta H_r^{\ominus}$, of this reaction?

compound	standard enthalpy change of combustion / kJ mol^{-1}
$C_6H_6(l)$	−3268
$H_2(g)$	−286
$C_6H_{12}(l)$	−3754

A −372 kJ mol^{-1} **B** −200 kJ mol^{-1} **C** +200 kJ mol^{-1} **D** +372 kJ mol^{-1}

13 Which equation represents the standard enthalpy change stated?

	standard enthalpy change of	equation
A	atomisation of $Cl_2(g)$	$Cl_2(g) \longrightarrow 2Cl(g)$
B	combustion of $H_2S(g)$	$H_2S(g) + O_2(g) \longrightarrow H_2(g) + SO_2(g)$
C	formation of $H_2SO_4(l)$	$2H(g) + 4O(g) + S(s) \longrightarrow H_2SO_4(l)$
D	solution of $K_2SO_4(s)$	$K_2SO_4(s) \longrightarrow 2K^+(aq) + SO_4^{2-}(aq)$

14 The kinetics of the following reaction is investigated, and the experimental data is given in the table below.

$$2R + 2S \longrightarrow T + U$$

[R] / mol dm^{-3}	[S] / mol dm^{-3}	initial rate / mol dm^{-3} s^{-1}
0.015	0.010	5.10×10^{-4}
0.030	0.020	4.08×10^{-3}
0.045	0.010	1.53×10^{-3}

What is the numerical value of the rate constant for this reaction?

A 0.00294 **B** 3.40 **C** 227 **D** 340

15 Ammonium carbamate, NH_2COONH_4, undergoes thermal decomposition.

$$NH_2COONH_4(s) \rightleftharpoons 2NH_3(g) + CO_2(g) \qquad \Delta H > 0$$

A vessel containing only NH_2COONH_4 is heated to 250 ^oC. The reaction reached equilibrium at time t_1. Subsequently both the temperature and volume of the vessel are decreased, and the reaction established a new equilibrium at time t_2.

Which statements are correct?

1 At t_2, $P_{NH_3} : P_{CO_2}$ is 2 : 1.

2 The rate of the forward reaction at t_1 is the same as that at t_2.

3 The degree of decomposition of NH_2COONH_4 at t_1 is smaller than that at t_2.

4 Decreasing the volume of the vessel at constant temperature has no effect on the equilibrium partial pressures of NH_3 and CO_2.

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

16 When a sample of iron(II) sulfate, $FeSO_4$, is heated to 920 K, reactions 1 and 2 occurred.

reaction 1 $2FeSO_4(s) \rightleftharpoons Fe_2O_3(s) + SO_3(g) + SO_2(g)$ K_1

reaction 2 $2SO_3(g) \rightleftharpoons 2SO_2(g) + O_2(g)$ K_2

At equilibrium, the total pressure is 0.836 atm and the partial pressure of oxygen is 0.0275 atm.

What is the value of K_2 at 920 K?

A 0.000147 **B** 0.0362 **C** 0.0476 **D** 0.160

17 The K_a of lactic acid is 1.4×10^{-4} mol dm^{-3} at 298 K.

A buffer solution contains 1.5 mol dm^{-3} lactic acid and 0.5 mol dm^{-3} sodium lactate.

Which statement correctly describes the buffer solution?

A The pH of the buffer solution is 4.33.

B The pH of the buffer solution decreases upon dilution with water.

C The buffering capacity of the buffer solution increases upon dilution with water.

D The buffer solution has a greater buffering capacity against a base compared to an acid.

18 Some equilibria, and the value of their equilibrium constants at 298 K, are given below.

$Cu^+(aq) + Cl^-(aq) \rightleftharpoons CuCl(s)$ $\quad K_1 = 8.33 \times 10^5$

$CuCl(s) + Cl^-(aq) \rightleftharpoons CuCl_2^-(aq)$ $\quad K_2 = 0.104$

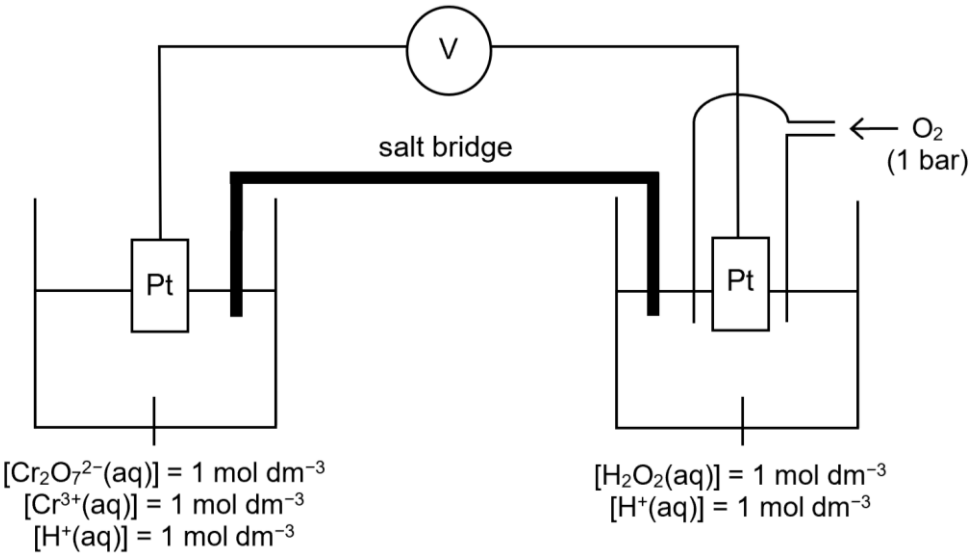
$Cu^+(aq) + 2Cl^-(aq) \rightleftharpoons CuCl_2^-(aq)$ $\quad K_3 = z$

Which row is correct?

	z	value of solubility product of CuCl(s) at 298 K
A	8.66×10^4	1.10×10^{-3}
B	8.66×10^4	1.20×10^{-6}
C	8.01×10^6	1.10×10^{-3}
D	8.01×10^6	1.20×10^{-6}

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

An electrochemical cell is set up under standard conditions as shown below.



Which change would result in an increase in cell potential?

A Addition of water to the O_2/H_2O_2 half-cell.

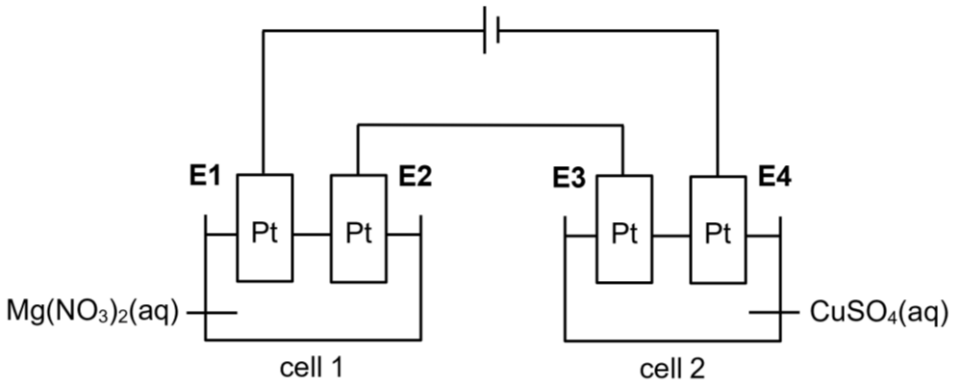
B Addition of KI(s) to the $Cr_2O_7^{2-}/Cr^{3+}$ half-cell.

C Using $O_2(g)$ of 1 atm pressure in the O_2/H_2O_2 half-cell.

D Using 2 mol dm^{-3} $Cr^{3+}(aq)$ in the $Cr_2O_7^{2-}/Cr^{3+}$ half-cell.

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

Cell 1 and cell 2 are connected in series as shown in the diagram below.



E1, **E2**, **E3** and **E4** are platinum electrodes.

After a current of 5 A is passed through the two cells for time *t*, the increase in mass of electrode **E4** is found to be 0.635 g.

Which statement is correct?

A *t* is 3.22 min.

B A white precipitate is formed around **E2**.

C Effervescence is observed only at **E1** and **E3**.

D The colour intensity of the solution in cell 2 remains unchanged.

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

The table below shows some vanadium-containing ions and their colours.

species	VO_2^+	VO^{2+}	V^{3+}	V^{2+}
colour in aqueous solution	yellow	blue	green	violet

A metal is added in excess to an aqueous solution containing VO_2^+. The resultant solution is violet in colour.

What is the identity of this metal?

A magnesium **B** silver **C** tin **D** zinc

22 When mixed with $Cr^{3+}(aq)$, ligands ***X*** and ***Y*** form complexes with Cr^{3+} as shown below.

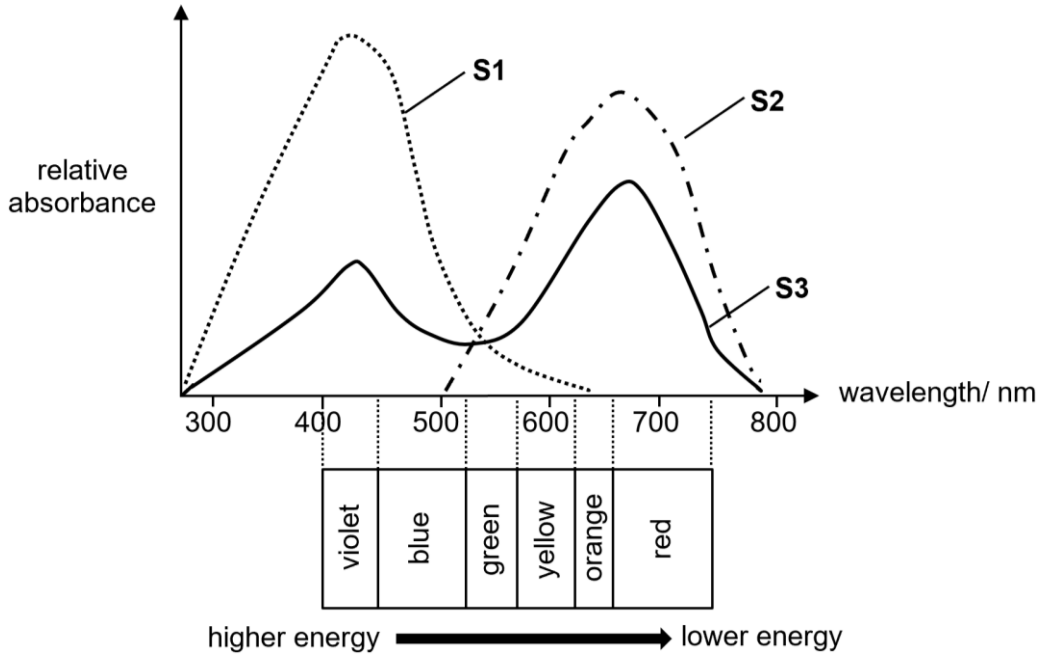
$$Cr^{3+}(aq) + 6\boldsymbol{X}(aq) \rightleftharpoons [Cr\boldsymbol{X}_6]^{3+}(aq)$$
$$Cr^{3+}(aq) + 6\boldsymbol{Y}(aq) \rightleftharpoons [Cr\boldsymbol{Y}_6]^{3+}(aq)$$

As the equilibrium constants for the above two reactions are large, $[Cr^{3+}(aq)]$ is very low in the presence of these ligands.

Solutions **S1**, **S2** and **S3** are prepared by mixing aqueous solutions of Cr^{3+}, ***X*** and ***Y*** of equal concentrations. The table below shows the volumes of each solution used.

	volume of solution / cm^3		
solution	$Cr^{3+}(aq)$	***X***(aq)	***Y***(aq)
S1	4	96	0
S2	4	0	96
S3	4	48	48

The absorption spectra of **S1**, **S2** and **S3** and the colours corresponding to the wavelengths of visible light are shown below.



The absorbance of a solution at a particular wavelength is proportional to the concentration of the species responsible for the absorbance.

Which of the following can be deduced from the information given above?

1 $[Cr\boldsymbol{Y}_6]^{3+}(aq)$ is orange in colour.

2 Cr^{3+} forms stronger bonds with ***Y*** than with ***X***.

3 The size of d-orbital splitting is larger in $[Cr\boldsymbol{X}_6]^{3+}$.

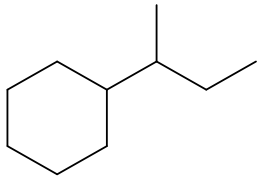
A 1, 2 and 3 **B** 1 and 2 only **C** 2 and 3 only **D** 1 only

23 The molecular formula for compound A is $C_{11}H_{14}O$. The structure of A includes an aldehyde group, a cyclohexene ring and a straight chain.

How many π bonds does A have?

A 2 **B** 3 **C** 4 **D** 5

24 Compound B ($C_{10}H_{20}$) is reacted with limited chlorine gas in the presence of ultra-violet light.



B

Assuming that only mono-chlorination takes place, which statements are correct?

1 Homolytic fission occurs in both initiation and propagation steps.

2 A total of eight possible mono-chlorinated products, ignoring stereoisomers, can be formed.

3 A compound with the formula $C_{20}H_{38}$ is found in small quantities in the mixture of products.

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

25 A catalytic converter is part of the exhaust system in modern cars.

Which reactions occur in the catalytic converter?

1 carbon monoxide + oxygen ⟶ carbon dioxide

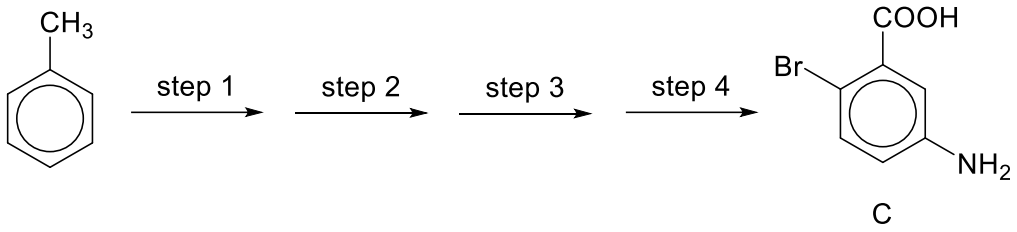
2 nitrogen dioxide + carbon monoxide ⟶ carbon dioxide + nitrogen

3 hydrocarbons + oxygen ⟶ carbon dioxide + water

4 hydrocarbons + carbon monoxide ⟶ carbon dioxide + water

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

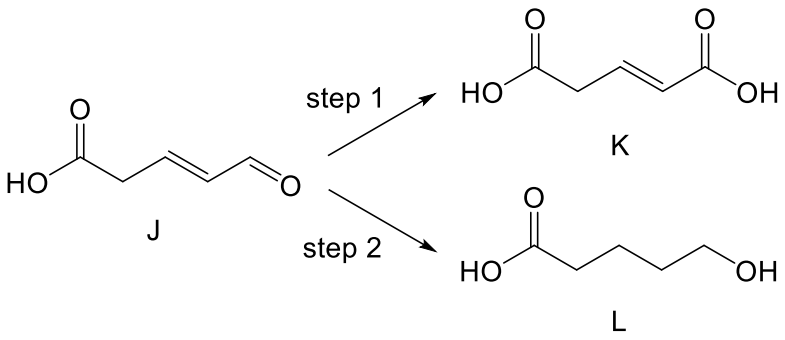
26 Which sequence of reactions would give the highest yield of compound C from methylbenzene?



C

	step 1	step 2	step 3	step 4
A	$KMnO_4$, H_2SO_4, heat	conc. HNO_3, conc. H_2SO_4, heat	Br_2, Fe	Sn, conc. HC*l*, heat, followed by NaOH
B	$KMnO_4$, H_2SO_4, heat	conc. HNO_3, conc. H_2SO_4, heat	Sn, conc. HC*l*, heat, followed by NaOH	Br_2, Fe
C	Br_2, Fe	conc. HNO_3, conc. H_2SO_4, heat	Sn, conc. HC*l*, heat, followed by NaOH	$KMnO_4$, H_2SO_4, heat
D	Br_2, Fe	$KMnO_4$, H_2SO_4, heat	conc. HNO_3, conc. H_2SO_4, heat	Sn, conc. HC*l*, heat, followed by NaOH

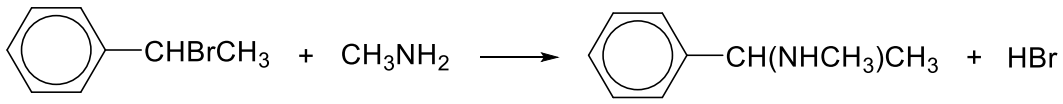
27 Compound J can be converted to compounds K and L as shown.



What could be the reagents and conditions for steps 1 and 2?

	step 1	step 2
A	$K_2Cr_2O_7$, H_2SO_4, heat	$NaBH_4$
B	$K_2Cr_2O_7$, H_2SO_4, heat	H_2, Ni, heat
C	$KMnO_4$, H_2SO_4, heat	$NaBH_4$
D	$KMnO_4$, H_2SO_4, heat	H_2, Ni, heat

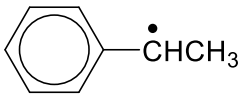
28 (1-Bromoethyl)benzene reacts with excess concentrated methylamine as shown below.



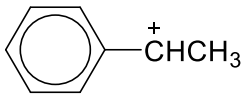
The rate of reaction is independent of the concentration of CH_3NH_2.

Which species could be formed during this reaction?

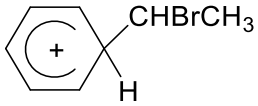
A



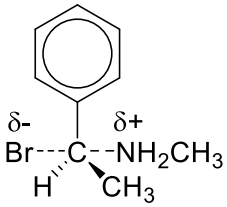
B



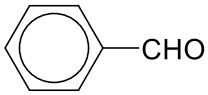
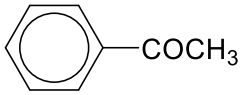
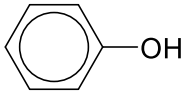
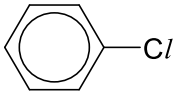
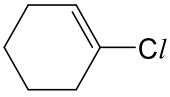
C



D



29 Which row correctly shows the reagent that can be used to distinguish between compounds 1 and 2?

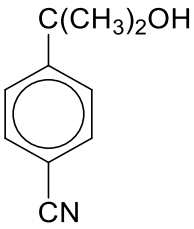
	compound 1	compound 2	reagent added
A	$CH_3CH_2NH_3^+Cl^-$	$(CH_3CH_2)_4N^+Cl^-$	hot aqueous NaOH
B			Fehling's solution
C		CH_3CH_2OH	aqueous Na_2CO_3
D			hot ethanolic $AgNO_3$

30 Compound W is tested with various reagents and gives the following results.

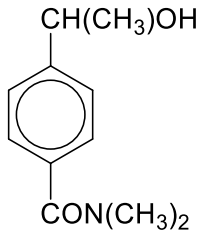
- W does not form a yellow precipitate with hot alkaline aqueous I_2.
- When W is treated with $LiAlH_4$ in dry ether, it forms a product that reacts with ethanoyl chloride in a 1:1 molar ratio.

What could W be?

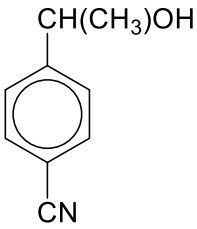
A



B



C



D