A LEVEL Cambridge Topical Past Papers

CHEMISTRY

PAPER 4 2020 — 2025

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1 - (9701/42_Summer_2020_Q5) ANSWER

(a) Define the term *partition coefficient,* K_{pc}.

.....

.....

..... [2]

(b) K_{pc} of benzoic acid between octan-1-ol and water is 79.4.

(i) A solution of 0.400 g of benzoic acid in 25.0 cm^3 octan-1-ol is shaken with 125 cm^3 of water.

Calculate the mass of benzoic acid extracted into the water layer.

mass of benzoic acid extracted = ... g [2]

(ii) K_{pc} of benzophenone, $C_6H_5COC_6H_5$, between octan-1-ol and water is different from the value of K_{pc} of benzoic acid given in **(b)(i)**.

Explain why.

.....

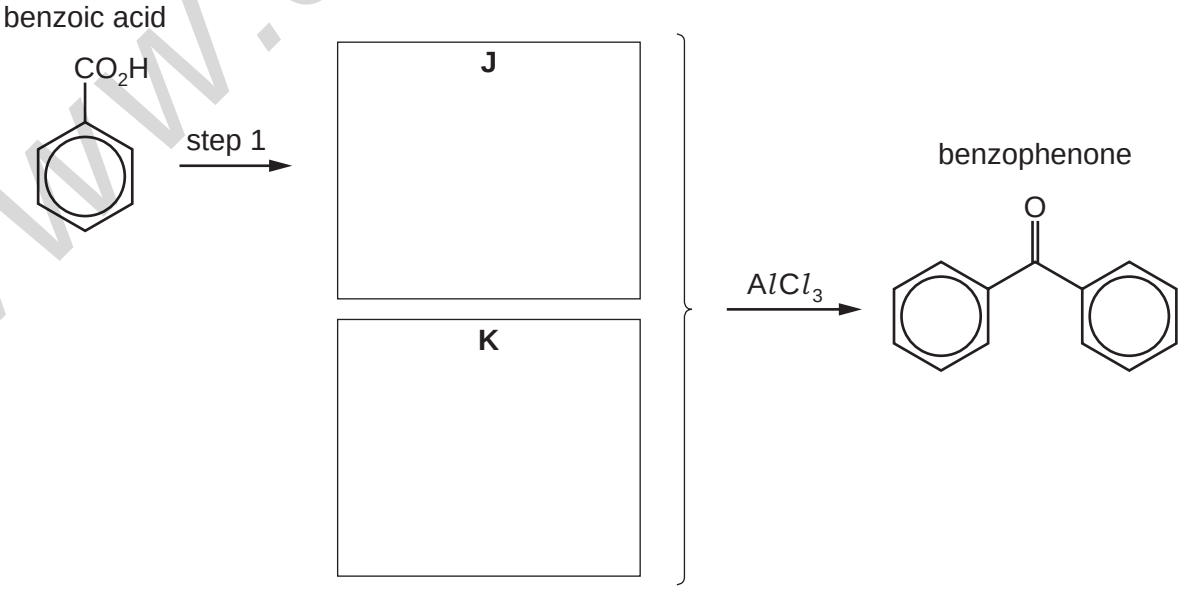
.....

..... [1]

(c) Benzophenone can be synthesised from benzoic acid in two steps as shown.

In step 1 compound **J**, a reactive reaction intermediate, is formed.

Compound **J** then reacts with an organic compound, **K**, to form benzophenone.



(i) Deduce the identities of organic compounds **J** and **K** and draw their structures in the boxes. [2]

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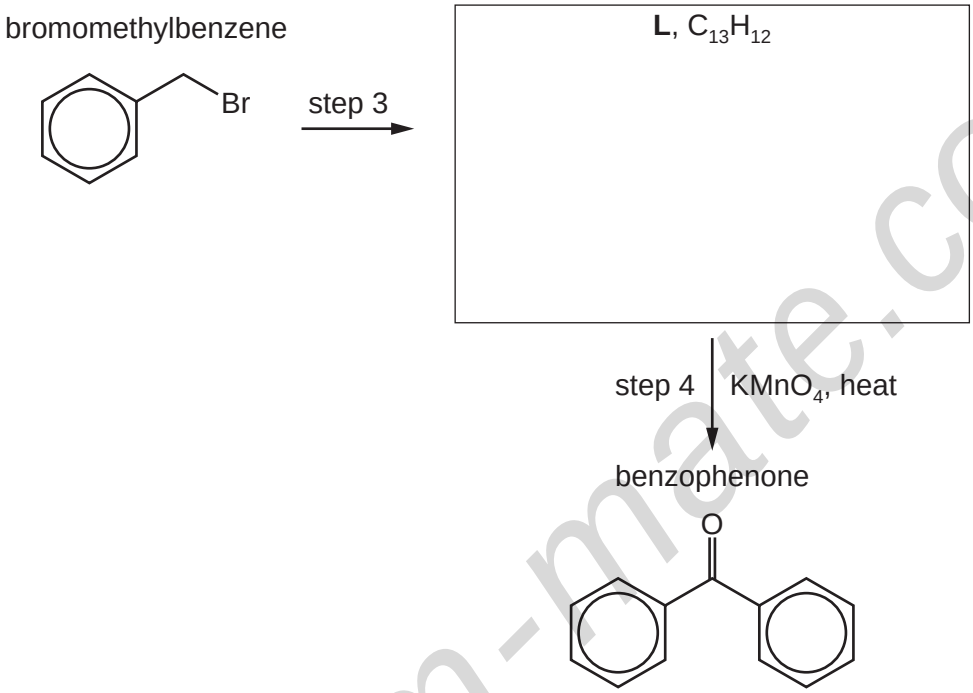
(ii) Suggest reagents and conditions for step 1.

..... [1]

(d) Benzophenone can also be synthesised in two steps from bromomethylbenzene.



(i) Deduce the identity of compound **L** and draw its structure in the box. [1]

(ii) Name the mechanism of step 3 and suggest reagents and conditions for step 3.

mechanism of step 3 .....

reagents and conditions .....

[2]

(iii) Deduce the *type of reaction* in step 4.

..... [1]

(e) (i) Deduce the number of peaks that would be present in the carbon-13 NMR spectrum of benzophenone.

number of peaks ..... [1]

(ii) Identify **two** different environments of carbon atom that would result in different chemical shift ranges in this carbon-13 NMR spectrum of benzophenone.

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environment of carbon atom	chemical shift range (δ)

[2]

[Total: 15]

2 - (9701/41_Winter_2021_Q4) ANSWER

Separate samples of 0.02 mol of calcium carbonate and 0.02 mol of barium carbonate are heated until completely decomposed to the metal oxide and carbon dioxide.

(a) State which of these two Group 2 carbonates requires the **higher** temperature before it begins to decompose. Explain your answer.

.....

.....

..... [2]

(b) After decomposition is complete, the 0.02 mol sample of calcium oxide is taken and added to 2.00 dm^3 of water. A solution is formed with no solid present. Dilute sulfuric acid is then added dropwise until a precipitate is seen.

The same procedure is repeated with the 0.02 mol sample of barium oxide, using the same concentration solution of dilute sulfuric acid.

Identify the sample to which **most** sulfuric acid must be added to cause a precipitate to appear.

Explain your answer. You should refer to the solubilities of the precipitates and relevant energy terms in your answer.

.....

.....

.....

..... [3]

(c) **(i)** Calculate the mass, in g, of CO_2 produced by the decomposition of 0.020 moles of calcium carbonate.

mass of CO_2 = ... g [1]

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(ii) Calculate the minimum mass, in g, of propane that would, on complete combustion, produce the same mass of CO_2 calculated in **(c)(i)**.
Give your answer to three significant figures.

mass of propane = ... g [2]

[Total: 8]

3 - (9701/41_Winter_2023_Q5) ANSWER

Transition elements behave as catalysts and can form complex ions.

(a) Explain why transition elements behave as catalysts.

.....

.....

..... [2]

(b) Silver forms the linear complex ion $[Ag(CN)_2]^-$.

Copper forms the tetrahedral complex ion $[Cu(CN)_4]^{3-}$.

Titanium forms the complex $[TiCl_4(diars)_2]$, where *diars* is a neutral bidentate ligand.

(i) State the oxidation state and the coordination number of titanium in $[TiCl_4(diars)_2]$.

oxidation state .....

coordination number .....

[1]

(ii) Draw three-dimensional diagrams to show the shapes of $[Ag(CN)_2]^-$ and $[Cu(CN)_4]^{3-}$, in the boxes.

Label one bond angle on each diagram.

Ag	Cu

[2]

(c) The numerical value of the stability constant, K_{stab}, of the copper(I) complex $[Cu(CN)_4]^{3-}$ is 2.0×10^{27}.

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(i) Write an expression for the K_{stab} of $[Cu(CN)_4]^{3-}$.

K_{stab} =

[1]

(ii) In a solution the concentrations of CN^- and $[Cu(CN)_4]^{3-}$ are both $0.0010\,mol\,dm^{-3}$.

Use your expression from **(c)(i)** and the value of K_{stab} to calculate the concentration of $Cu^+(aq)$ in this solution.

concentration of $Cu^+(aq)$ = ... $mol\,dm^{-3}$ [1]

(d) A piece of a copper-containing alloy has a mass of 0.567 g. It is dissolved in an acid giving $100.0\,cm^3$ of a blue solution in which all the copper is present as Cu^{2+} ions.

An excess of KI(aq) is added to a $25.0\,cm^3$ sample of this solution.

All of the copper is precipitated as white CuI(s).

Cu^{2+} ions are the only component in the solution that react with KI(aq). This is reaction 1.

reaction 1 $2Cu^{2+} + 4I^- \rightarrow 2CuI + I_2$

The liberated I_2 is then titrated with $0.0200\,mol\,dm^{-3}$ $S_2O_3^{2-}$. This is reaction 2.

reaction 2 $I_2 + 2S_2O_3^{2-} \rightarrow 2I^- + S_4O_6^{2-}$

The titration requires $20.10\,cm^3$ of $0.0200\,mol\,dm^{-3}$ $S_2O_3^{2-}$ to reach the end-point.

(i) Calculate the number of moles of I_2 that are reduced in this titration.

number of moles of I_2 = ... mol [1]

(ii) Calculate the number of moles of copper in the original piece of alloy.

number of moles of copper = ... mol [1]

(iii) Calculate the percentage of copper in the alloy.

percentage of copper = ... % [1]

(iv) Suggest why a solution of Cu^{2+} is coloured but solid CuI is white.

.....

.....

..... [2]

[Total: 12]

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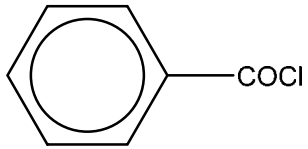
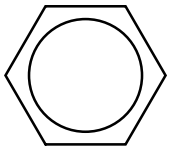
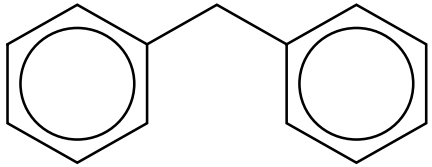
1 - (9701/42_Summer_2020_Q5) QUESTION

(a)	**M1** ratio of the concentration of a solute in the two immiscible solvents /liquids **M2** at equilibrium	**2**
(b)(i)	**M1** 79.4 = (0.4-x/25)/(x/125) **M2** x = **0.0237** g [2] min 2sf	**2**
(b)(ii)	(higher as) benzophenone is more non-polar/more soluble in octan-1-ol **ora**	**1**
(c)(i)	J =  K =  Award one mark for each correct structure	**2**
(c)(ii)	step 1 PCl_5 **OR** $SOCl_2$ **OR** PCl_3 + heat	**1**
(d)(i)		**1**
(d)(ii)	**M1** step 3 electrophilic substitution **M2** step 3 benzene and $AlCl_3$ (and heat)	**2**
(d)(iii)	step 4 oxidation	**1**
(e)(i)	5 peaks	**1**

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(e)(ii)	<table><tr><th>environment of carbon atom</th><th>chemical shift range (δ)</th></tr><tr><td>carbonyl / RCOR</td><td>190–220</td></tr><tr><td>arene / benzene</td><td>110–160</td></tr></table> Award one mark for each correct for each row	**2**

2 - (9701/41_Winter_2021_Q4) QUESTION

(a)	• barium carbonate / Ba / $BaCO_3$ • larger ionic radius **OR** smaller charge density of cation / M^{2+} [1] • anion / CO_3^{2-} / carbonate ion is less distorted / less polarised **OR** C-O / C=O less weakened [1]	**2**
(b)	• calcium oxide / calcium hydroxide • Ca**SO_4 /** calcium **sulfate** is more soluble **OR** Ba**SO_4** is less soluble [1] • ΔH_{latt} and ΔH_{hyd} are less exothermic / more endothermic (for $BaSO_4$) [1] • ΔH_{hyd} is dominant factor / ΔH_{hyd} change is greater **OR** ΔH_{latt} changes less [1]	**3**
(c)(i)	mass of CO_2 = 0.02×44 = **0.88** g [1]	**1**
(c)(ii)	(writes correct equation, deduces 3 CO_2 per mole) moles of propane = 0.02 / 3 **OR** 0.00667 **OR** 1 / 150 [1] mass of propane = $0.02 / 3 \times 44$ = **0.293** g [1] ecf M1 $\times$ 44 3sf needed	**2**

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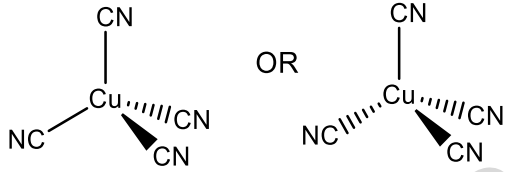
3 - (9701/41_Winter_2023_Q5)

(a)	more than one (stable) oxidation state [1] empty / vacant (d) orbitals are energetically accessible OR empty / vacant (d) orbitals can form dative bonds with ligands [1]	**2**
(b)(i)	oxid. no. = + 4 AND coord. no. = 8 [1]	**1**
(b)(ii)	bond angle must go from bond to bond OR CN group to CN group diagram • for Ag: NC—Ag—CN • angle = labelled 180°  • for Cu: • angle = labelled 109–110° any two [1] all four [2]	**2**
(c)(i)	K_{stab} = $[[Cu(CN)_4]^{3-}] / [Cu^+] [CN^-]^4$ [1] ALLOW use of $[[Cu(H_2O)_6]^+]$	**1**
(c)(ii)	[Cu+] = 5.0×10^{-19} (mol dm^{-3}) [1] min 1sf ECF from reversed ratio **5(c)(i)**	**1**
(d)(i)	mol of I_2 = $0.5 \times 0.02 \times 20.1 / 1000 = 2.01 \times 10^{-4}$ [1] min 2sf	**1**
(d)(ii)	mol of Cu = $2.01 \times 10^{-4} \times 2 \times 4 = 1.608 / 1.61 \times 10^{-3}$ [1] ecf min 2sf	**1**
(d)(iii)	% of Cu = $100 \times (1.608 \times 10^{-3} \times 63.5) / 0.567 = 18.0$ [1] ecf	**1**

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