A LEVEL Cambridge Topical Past Papers

CHEMISTRY

PAPER 2 2017 — 2023

CHEMISTRY 9701

TOPICAL PAST PAPER WORKSHEETS

2017 - 2023 | Questions + Mark scheme

AVAILABLE PAPERS

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P2 299 Questions

P4 365 Questions

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1 - (9701/21_Summer_2017_Q1) - *Atoms,molecules & Stoichiometry, Hydroxy Compounds*

Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds.

(a) Define the term *relative molecular mass*.

....

....

....

.... [2]

(b) **T** is an alcohol, C_xH_yO. A gaseous sample of **T** occupied a volume of $20\,cm^3$ at 120 °C and 100 kPa.

The sample was completely burned in $200\,cm^3$ of oxygen (an excess). The final volume, measured under the same conditions as the gaseous sample, was $250\,cm^3$.

Under these conditions, all water present is vaporised. Removal of the water vapour from the gaseous mixture decreased the volume to $170\,cm^3$.

Treating the remaining gaseous mixture with concentrated alkali, to absorb carbon dioxide, decreased the volume to $110\,cm^3$.

The equation for the complete combustion of **T** can be represented as shown.

$$C_xH_yO + zO_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

(i) Use the data given to calculate the value of *x*.

x = ... [1]

(ii) Use the data given to calculate the value of *y*.

y = ... [1]

If you were unable to calculate values for *x* and *y* then use *x* = 4 and *y* = 10 for the remaining parts of this question. These are **not** the correct values.

(iii) Complete the equation for the complete combustion of the alcohol, **T**.

.... + ...O_2 → ....CO_2 + ...H_2O

[1]

(iv) Give the skeletal formulae for two possible structures of **T**.

Name each alcohol.

....	....

[2]

(v) Use the general gas equation to calculate the mass of **T** present in the original 20 cm^3 gaseous sample, which was measured at 120 °C and 100 kPa.

Give your answer to **three** significant figures. Show your working.

mass = ... g [3]

2 - (9701/22_Summer_2017_Q1) - *Atoms,molecules & Stoichiometry, Atomic Structure*

The composition of atoms and ions can be determined from knowledge of atomic number, nucleon number and charge.

(a) Complete the table.

atomic number	nucleon number	number of electrons	number of protons	number of neutrons	symbol
3		2			$^{6}_{3}Li^{+}$
		23	26	32	

[2]

(b) Boron occurs naturally as a mixture of two stable isotopes, ^{10}B and ^{11}B. The relative isotopic masses and percentage abundances are shown.

isotope	relative isotopic mass	abundance / %
^{10}B	10.0129	19.78
^{11}B	to be calculated	80.22

(i) Define the term *relative isotopic mass*.

....

.... [2]

(ii) Calculate the relative isotopic mass of ^{11}B.

Give your answer to **six** significant figures. Show your working.

[2]

3 - (9701/23_Summer_2017_Q1) - *Atoms,molecules & Stoichiometry, States Of Matter, An Introduction To Organic Chemistry*

Combustion data can be used to calculate the empirical formula, molecular formula and relative molecular mass of many organic compounds. Combustion data cannot distinguish between different structural isomers.

(a) Define the term *structural isomers*.

....

....

....

.... [2]

(b) **P** is a hydrocarbon, C_xH_y. A gaseous sample of **P** occupied a volume of $25\,cm^3$ at 37 °C and 100 kPa.

The sample was completely burned in $200\,cm^3$ of oxygen (an excess).
The final volume, measured under the same conditions as the gaseous sample (so that the water produced is liquid and its volume can be ignored), was $150\,cm^3$.

Treating the remaining gaseous mixture with concentrated alkali, to absorb carbon dioxide, decreased the volume to $50\,cm^3$.

The equation for the complete combustion of **P** can be represented as shown.

$$C_xH_y + (x + \frac{y}{4})O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

(i) Use the data given to calculate the value of x.

x = ... [1]

(ii) Use the data given to calculate the value of $(x + \frac{y}{4})$.

$(x + \frac{y}{4})$ = ... [1]

If you were unable to calculate values in **(b)(i)** and **(b)(ii)** then use the data in this box for the remaining parts of this question. These are **not** the correct values.

$x = 6$ $(x + \frac{y}{4}) = 9$

(iii) Give the molecular formula and the empirical formula of **P**.

molecular formula of **P** ....

empirical formula of **P** .... [2]

(iv) **P** is unbranched.

Give the skeletal formulae for two possible structures of **P** that are positional isomers of each other.

[2]

(v) Use the general gas equation to calculate the mass of **P** present in the original $25\,cm^3$ gaseous sample, which was measured at 37 °C and 100 kPa.

Give your answer to **three** significant figures.

mass = ... g [3]

4 - (9701/22_Summer_2018_Q2) - *Chemical Bonding, Atoms,molecules & Stoichiometry*

Ammonium iron(II) sulfate, $(NH_4)_2Fe(SO_4)_2$, has a relative formula mass, M_r, of 284.

(a) Define the term *relative formula mass*.

....

....

....

.... [2]

(b) One of the cations in ammonium iron(II) sulfate is the ammonium ion, NH_4^+.

(i) Draw a 'dot-and-cross' diagram of an ammonium ion. Show outer shell electrons only.

Use × to show electrons from nitrogen.
Use ● to show electrons from hydrogen.

[2]

(ii) Suggest the shape of an ammonium ion and predict the bond angle.

shape ....

bond angle ....
[2]

(c) In aqueous solution the ammonium ion acts as a weak Brønsted-Lowry acid.

(i) Explain the meaning of the term *weak Brønsted-Lowry acid*.

....

....

....

.... [2]

(ii) Write an equation to show this behaviour of the ammonium ion in water. Include state symbols.

.... [2]

(d) Mohr's salt, $(NH_4)_2Fe(SO_4)_2•xH_2O$, is the hydrated form of ammonium iron(II) sulfate.

x represents the number of moles of water in 1 mole of the salt.

A student wanted to determine the value of x. 0.784 g of the hydrated salt was dissolved in water and this solution was acidified.

All of the solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII). 20.0 cm^3 of this potassium manganate(VII) solution was required for complete reaction with the Fe^{2+} ions.

(i) Use changes in oxidation numbers to balance the equation for the reaction taking place.

$MnO_4^-(aq)$ + ...$Fe^{2+}(aq)$ + ...$H^+(aq)$ → .....$Mn^{2+}(aq)$ + ...$Fe^{3+}(aq)$ + ...$H_2O(l)$

[1]

(ii) State the role of the Fe^{2+} ions in this reaction.

Explain your answer.

....

.... [2]

(iii) Calculate the amount, in moles, of manganate(VII) ions that reacted.

amount = ... mol [1]

(iv) Calculate the amount, in moles, of Fe^{2+} ions in the sample of the salt.

amount = ... mol [1]

(v) Calculate the relative formula mass of $(NH_4)_2Fe(SO_4)_2{\bullet}xH_2O$.

relative formula mass = ... [1]

(vi) Calculate the value of x.

x = ... [1]

5 - (9701/22_Summer_2018_Q4) - *Carbonyl Compounds, Atoms,molecules & Stoichiometry*

W is $CH_3COCH_2CH_3$.

(a) The reaction between **W** and alkaline aqueous iodine produces a yellow precipitate.

(i) Give the name of the compound formed as a yellow precipitate in this reaction.

.... [1]

(ii) Give the name of **W**.

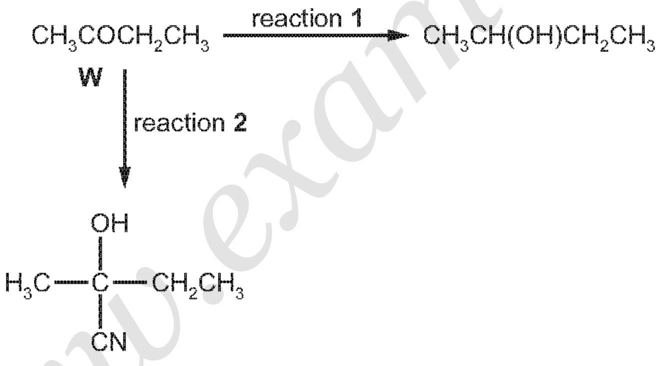
.... [1]

(b) There are two structural isomers of **W** that are also carbonyl compounds.

Draw the structures of these two isomers of **W**.

[2]

Two reactions of **W** are shown.



X

(c) **(i)** Identify the type of reaction occurring in reaction **1**.

.... [1]

(ii) Identify the reagent for reaction **1**.

.... [1]

(d) Reaction **2** is carried out by adding a mixture of HCN and NaCN to **W**.
The product, **X**, is formed as a mixture of two isomers.

(i) Complete the mechanism for this reaction.

Include the structure of the intermediate formed and all necessary charges, dipoles, lone pairs and curly arrows.

W

CN^-

X

[4]

(ii) State the name of the type of isomerism shown by **X**.

.... [1]

(iii) Explain fully why **X** shows this type of isomerism.

....

....

....

.... [2]

(e) If **X** is treated with ammonia and the product hydrolysed, a compound, **Y**, is obtained that contains 51.3% C, 9.40% H, 12.0% N and 27.3% O by mass.

(i) Show that the empirical formula of **Y** is $C_5H_{11}NO_2$.

[2]

(ii) The empirical formula of **Y** is $C_5H_{11}NO_2$ and the M_r of **Y** is 117.

Deduce the molecular formula of **Y**. You **must** explain your reasoning.

molecular formula = ...

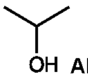
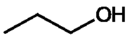
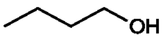
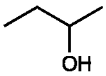
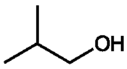
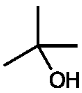
....

....

[1]

ANSWERS

1 – (9701/21_Summer_2017_Q1) – *Atoms,molecules & Stoichiometry, Hydroxy Compounds*

(a)	The mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecules
	Relative / compared to $\frac{1}{12}$ (the mass) of <u>an atom</u> of carbon–12 OR on a scale in which a carbon–12 atom / isotope has a mass of (exactly) 12 (units)
(b)(i)	**3**
(b)(ii)	**8**
(b)(iii)	$C_3H_8O + 4\frac{1}{2}O_2 \rightarrow 3CO_2 + 4H_2O$
(b)(iv)	 **AND** propan–2–ol / 2–propanol
	 **AND** propan–1–ol / 1–propanol
	Alternative answers (any two):  **AND** butan–1–ol / 1–butanol  **AND** butan–2–ol / 2–butanol  **AND** (2–)methylpropan–1–ol / (2–)methyl–1–propanol  **AND** (2–)methylpropan–2–ol / (2–)methyl–2–propanol

(b)(v)	correct conversions of data to SI/consistent units $p = 100\,000$; $V = 20 \times 10^{-6}$; $T = 393$
	calculation of *n* (= *pV*/*RT*) from M1 values $n = \frac{100 \times 10^3 \times 20 \times 10^{-6}}{8.31 \times 393}$
	calculation of mass *m* (= *n* × *Mr*) **AND** answer correct to **3sf** $m = 6.12 \times 10^{-4} \times 60 = 0.0367$ (g) Alternative answer for using $C_4H_{10}O$: $m = 6.12 \times 10^{-4} \times 74 = 0.0453$ (g)

2 - (9701/22_Summer_2017_Q1) - *Atoms,molecules & Stoichiometry, Atomic Structure*

(a)

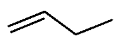
atomic number	nucleon number	number of electrons	number of protons	number of neutrons	symbol
	6		3	3	
					$^{58}_{26}Fe^{3+}$

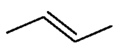
(b)(i)	EITHER mass of an atom / isotope relative / compared to 1/12 (the mass) of (an atom of) C-12 OR on a scale in which a C-12 (atom / isotope) has (a mass of exactly) 12 (units) OR mass of one mol (of atoms) of an isotope relative / compared to 1/12 (the mass) of 1 mol of C-12 OR on a scale in which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g
(b)(ii)	$\frac{(10.0129 \times 19.78) + (80.22x)}{100} = 10.8$
	x = 10.9941

3 - (9701/23_Summer_2017_Q1) - *Atoms,molecules & Stoichiometry, States Of Matter, An Introduction To Organic Chemistry*

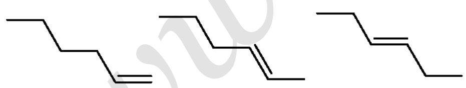
(a)	(molecules / isomers with) the same molecular formula / same number of atoms of each element
	different structural / displayed formulae / different arrangement of bonds
(b)(i)	4
(b)(ii)	6
(b)(iii)	molecular = C_4H_8
	empirical = CH_2 using alternative supplied data molecular = C_6H_{12} empirical = CH_2

(b)(iv)



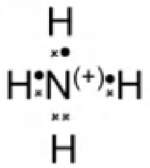


alternative using supplied data: any two



(b)(v)	correct conversions of data to SI / consistent units P = 100 000; V = 25 × 10^{-6}; T = 310
	calculation of *n* (= *pV* / *RT*) $n = \frac{100 \times 10^3 \times 25 \times 10^{-6}}{8.31 \times 310}$
	calculation of mass *m* (= *n* × M_r) AND answer correct to **3sf** $m = 9.705 \times 10^{-4} \times 56 = 0.0543$ (g)
	Alternative answer for using C_6H_{12}: $m = 9.705 \times 10^{-4} \times 84 = 0.0815$ (g)

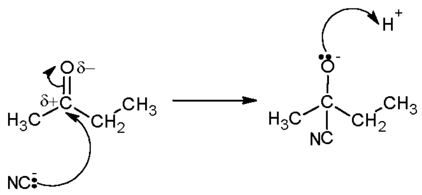
4 - (9701/22_Summer_2018_Q2) - *Chemical Bonding, Atoms,molecules & Stoichiometry*

(a)	*option 1:* the mass of (all the atoms/ions in) a formula (unit) / molecule OR the (weighted) average / (weighted) mean mass of (all the atoms / ions in) the formula (unit) / molecule [1] relative / compared to 1 / 12 (the mass of an atom) of carbon–12 OR on a scale in which a carbon–12 (atom / isotope) has a (mass) of (exactly) 12 (units) [1] *option 2:* mass of one mol of a compound / formula (unit) / molecule [1] relative / compared to 1 / 12 (the mass) of 1 mol of C-12 OR in which one mol C-12 (atom / isotope) is (a mass of exactly) 12 g [1]	2
(b)(i)		
	4 shared pairs only (any symbols) (in NH_4)	1
	3 × dot-and-cross bonds AND 1 × 2 crosses (in NH_4)	1
(b)(ii)	tetrahedral	1
	109–109.5° (inclusive)	1

c(i)	*in any order explain meaning of:* *weak* partially ionises / incompletely dissociates (into ions) *Bronsted-Lowry acid* is a proton donor / H^+ (ion) donor / hydrogen ion donor	2
c(ii)	$NH_4^+(aq) + H_2O(l) \rightleftharpoons NH_3(aq\ or\ g) + H_3O^+(aq)$	
	all correct species and balancing	1
	correct state symbols	1
(d)(i)	$MnO_4^- + \mathbf{5}Fe^{2+} + \mathbf{8}H^+ \rightarrow Mn^{2+} + \mathbf{5}Fe^{3+} + \mathbf{4}H_2O$	1
(d)(ii)	(Fe^{2+} is a) reducing agent / reductant provides/donates electron(s) / loses electron(s) / increases its oxidation number / (Fe^{2+}) becomes Fe^{3+}	2
(d)(iii)	4×10^{-4} / 0.0004	1
(d)(iv)	2×10^{-3} / 0.002	1
(d)(v)	392	1
(d)(vi)	6	1

5 - (9701/22_Summer_2018_Q4) - *Carbonyl Compounds, Atoms,molecules & Stoichiometry*

(a)(i)	iodoform / tri-iodomethane	1
(a)(ii)	butanone	1

(b)	$CH_3CH_2CH_2CHO$	**1**
	$(CH_3)_2CHCHO$	**1**
(c)(i)	reduction	**1**
(c)(ii)	$NaBH_4$ / sodium borohydride OR $LiAlH_4$ / lithium aluminium hydride	**1**
(d)(i)		
	lone pair on C of CN^- and curly arrow to C of C=O	**1**
	correct dipole on C=O and curly arrow from = to O	**1**
	correct intermediate anion	**1**
	curly arrow from lone pair on O to H^+	**1**

(d)(ii)	optical	**1**
(d)(iii)	(X has a) chiral centre / asymmetric carbon atom OR (X has a) C atom attached to four different groups / atoms / chains	**1**
	non-super(im)posable mirror images	**1**
(e)(i)	*M1 is for the process of taking the % of each element and dividing by its relative atomic mass.* C H N O $\frac{51.3}{12}$ $\frac{9.40}{1}$ $\frac{12.0}{14}$ $\frac{27.3}{16}$ OR 4.28 9.40 0.857 1.71 *M2 is for dividing the smallest %/A_r into each of the remaining values to produce the correct ratio.* $\frac{4.28}{0.857}$ $\frac{9.40}{0.857}$ $\frac{0.857}{0.857}$ $\frac{1.71}{0.857}$ OR 4.9942 : 10.9685 : 1 : 1.9953	**2**
(e)(ii)	$C_5H_{11}NO_2$ **AND** because the EFM = RFM	**1**