CAMBRIDGE INTERNATIONAL AS & A LEVEL CHEMISTRY · 9701

CHEMISTRY



MARK SCHEME

22 ANALYTICAL TECHNIQUES

SCORE	PERCENTAGE
/	%

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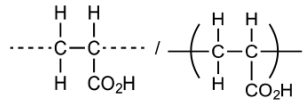
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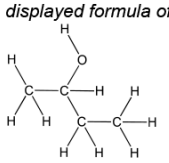
Paper 1 Multiple Choice Answers: Analytical Techniques

Question	Paper	Q. No.	Answer
1188	9701_m22_qp_12	40	B
1189	9701_m21_qp_12	30	B
1190	9701_s21_qp_11	17	D
1191	9701_s21_qp_11	26	A
1192	9701_s21_qp_12	30	D
1193	9701_s21_qp_13	30	D
1194	9701_w21_qp_11	30	B
1195	9701_w21_qp_12	30	B
1196	9701_w21_qp_13	30	B
1197	9701_m20_qp_12	23	C
1198	9701_s20_qp_11	29	A
1199	9701_s20_qp_12	21	C
1200	9701_s20_qp_13	7	C
1201	9701_s20_qp_13	25	C
1202	9701_w20_qp_12	30	C
1203	9701_m19_qp_12	30	C
1204	9701_s19_qp_11	2	D
1205	9701_s19_qp_11	24	B
1206	9701_s19_qp_12	2	B
1207	9701_s19_qp_12	30	C
1208	9701_s19_qp_13	2	C
1209	9701_w19_qp_11	30	D
1210	9701_w19_qp_12	30	A
1211	9701_m18_qp_12	30	B
1212	9701_s18_qp_11	30	C
1213	9701_s18_qp_12	30	C
1214	9701_s18_qp_13	30	B
1215	9701_w18_qp_11	30	C
1216	9701_w18_qp_12	30	C
1217	9701_s17_qp_11	2	D
1218	9701_s16_qp_13	4	C
1219	9701_w21_qp_11	1	A
1220	9701_w21_qp_12	1	A
1221	9701_w21_qp_13	1	A

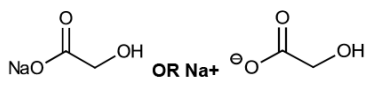
160. 9701_m21_ms_22 Q: 3

Question	Answer	Marks
(d)(i)	addition polymerisation	1
(d)(ii)		1
(d)(iii)	propan-1-amine / 1-aminopropane	1
(d)(iv)	alcoholic / ethanolic solution **AND** high pressure / heat in a sealed container	1

161. 9701_s21_ms_22 Q: 5

Question	Answer	Mark
(a)	*displayed formula of butan-2-ol structure with O—H shown* 	1
(b)(i)	2-bromobutane	1
(b)(ii)	substitution	1
(b)(iii)	*reagent* **M1** NaCN or KCN	1
	conditions **M2** ethanolic AND heat (under reflux)	1
(b)(iv)	(1)C_4H_9CN + (1)H^+ + 2H_2O → (1)$C_4H_9CO_2H$ + (1)NH_4^+ ✓✓ *correct organic product showing carboxylic acid functional group* **M1** $C_4H_9CO_2H$ / C_4H_9COOH	1
	M2 balanced equation with a $C_5H_{10}O_2$ or equivalent structure as product	1
(b)(v)	2200–2250 (cm^{-1} due to) C≡N / triple bond between C and N.	1

162. 9701_w21_ms_21 Q: 4

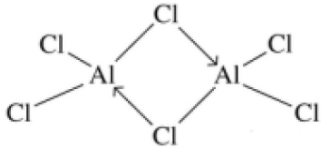
Question	Answer	Marks
(a)(i)	potassium/sodium dichromate [(VI)] / $K_2Cr_2O_7$ / $Na_2Cr_2O_7$ acidified **AND** (heat) under reflux	2
(a)(ii)	$C_2H_5OH + 2[O] \rightarrow CH_3CO_2H + H_2O$	1
(a)(iii)	substitution	1
(a)(iv)	in the same phase / in same state	1
(b)	**M1** ester **M2** 1100 cm^{-1} linked to C—O **AND** 1720 cm^{-1} linked to C=O **M3** No COOH / carboxylic acid and No OH / alcohol in D (but present in C) **OR** COOH / carboxylic acid and OH / alcohol reacted /lost (in C to form D)	3
(c)(i)		1
(c)(ii)	Not a strong (enough) reducing agent	1

Question	Answer	Marks
(c)(iii)	*Construct an equation* $(CH_2OH)_2 + SOCl_2 \rightarrow (CH_2Cl)_2 + SO_2 + H_2O$	1
(d)	Forms hydrogen bonds **with water**	1

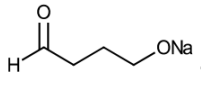
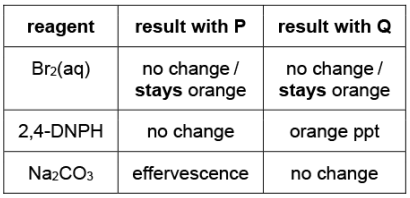
163. 9701_s20_ms_21 Q: 6

(a)		1
(b)(i)	hot **AND** concentrated	1
(b)(ii)	oxidation	1
(c)	*Structural formula of **X**:* HCO_2H OR HCOOH	1
(d)	**M1** *reagent* (2,4–) DNPH / (2,4)-dinitrophenylhydrazine **M2** *observation* yellow / orange / red precipitate	2
(e)	*Predict **two** differences, with reasons, between spectra of **Y**, $CH_3CH_2COCH_3$ and 2-methylbut-1-ene (shown)* *first difference* **M1** absence of peak/ absorption at 3100 (cm^{-1}) as no longer any =C–H present (in **Y**) *second difference* **M2** peak at 1650 (cm^{-1}) moves to the left to any value / range of values between 1670 and 1740) due to disappearance of C=C (in **Y**) and appearance of C=O (in **Y**) OR absence of peak at 1650 (cm^{-1}) as no longer any C=C present (in **Y**) AND appearance of peak (in **Y**) at (any value / range of values) between 1670-1740(cm^{-1}) due to C=O	2
(f)(i)	$CH_3CH_2CO_2H + 4[H] \rightarrow CH_3CH_2CH_2OH + H_2O$	1
(f)(ii)	propan-1-ol ALLOW propan-2-ol as error carried forward from **6f(i)**	1
(g)(i)	*Molecular formula of **W*** $C_3H_6O_2$	1
(g)(ii)	*Possible structure of **W*** CH_3COOCH_3 **OR** $HCOOCH_2CH_3$	1

164. 9701_w20_ms_21 Q: 3

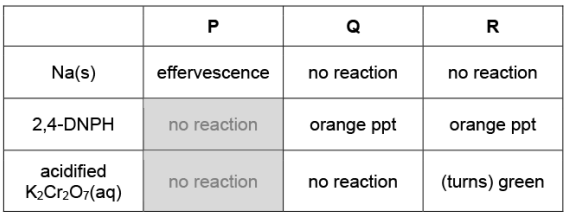
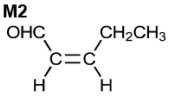
(a)(i)	**M1:** *correct representation of Al_2Cl_6, dot and cross or line diagram*  **M2: TWO** correct co-ordinate bonds identified	**2**
(a)(ii)	120	**1**
(a)(iii)	Li^+ is $1s^2$ H^- is $1s^2$	**1**
(a)(iv)	(Lattice of) cations / positive ions surrounded by **delocalised** electrons'	**1**
(b)	$Al(OH)_3$ / aluminium hydroxide	**1**
(c)(i)	**M1:** potassium dichromate[(VI)] **M2:** acid(ified) AND (heat under) **reflux**	**2**
(c)(ii)	**(M1:** *correct identity of **R** and statement re: reaction 3 ONLY ketone reduced*) **R** (is 2-hydroxybutanoic acid) **AND** as (only) C=O / ketone reduced **(M2:** *correct explanation re: strength of reducing agents*) $NaBH_4$ cannot reduce the COOH / **carboxylic acid** **OR** $LiAlH_4$ can reduce the COOH / **carboxylic acid**	**2**
(c)(iii)	 **M1:** Presence of :CN (if bonding shown, must be unambiguous triple bond) **M2:** curly arrow from :CN lone pair to carbonyl carbon **M3:** correct dipole **AND** curly arrow from double bond to oxygen **M4:** correct intermediate drawn	**4**
(c)(iv)	$C_2H_5CH(OH)CN$ + **HCl + $2H_2O$** → $C_2H_5CH(OH)COOH$ + **NH_4Cl**	**1**
(c)(v)	Any two of three absorption references: • absorption 2200–2250 (cm^{-1}) shows presence of C≡N • lack of absorption at 1680–1730 (cm^{-1}) shows lack of C=O • lack of absorption at 2500–3000 (cm^{-1}) shows lack of RCO_2–H / O–H in RCO_2H	**2**

165. 9701_w20_ms_22 Q: 4

(a)(i)	oxidation	1
(a)(ii)	**M1:** potassium dichromate[(VI)] **M2:** acid(ified) AND (heat under) **reflux**	2
(a)(iii)	*structure of **H***  OR $CHO(CH_2)_2CH_2O^-Na^+$	1
(a)(iv)	(formation of) silver mirror / ppt	1
(a)(v)	esterification	1
(b)(i)	positional (isomerism) / regioisomerism	1
(b)(ii)	**M1:** add aqueous alkaline iodine	2
	M2: G no change **AND J** yellow ppt	
(b)(iii)	reducing agent	1
(b)(iv)	(1,3-)butadiene OR buta(-1,3-)diene OR 	1
(c)	 Award one mark for every two correct observations.	3
(d)(i)	X is C=O **AND** Z is C—O	1
(d)(ii)	hexanoic acid	1
(d)(iii)	$C_{12}H_{20}O_2$	1

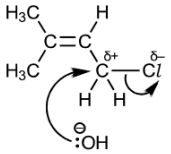
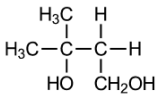
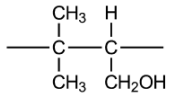
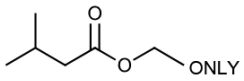
reagent	**result with P**	**result with Q**
$Br_2(aq)$	no change / **stays** orange	no change / **stays** orange
2,4-DNPH	no change	orange ppt
Na_2CO_3	effervescence	no change

166. 9701_m19_ms_22 Q: 3

(a)		3
(b)	$C_5H_{10}O + 2[H] \rightarrow C_5H_{12}O$	1
(c)	**M1** geometric(al) **M2** 	2
(d)	**M1** compound **P** **M2** (absorption at) 2250 cm^{-1} **AND** C≡N (stretch) **M3** (absorption at) 3100–3700 cm^{-1} **AND** O—H (stretch)	3

	P	**Q**	**R**
Na(s)	effervescence	no reaction	no reaction
2,4-DNPH	no reaction	orange ppt	orange ppt
acidified $K_2Cr_2O_7(aq)$	no reaction	no reaction	(turns) green

167. 9701_w19_ms_22 Q: 4

(a)	 **M1:** curly arrow from lone pair on O of OH^- to C of C—Cl **M2:** correct dipole on C—Cl **AND** curly arrow from C—Cl bond to $Cl^{\delta-}$	**2**
(b)(i)		**1**
(b)(ii)	$(CH_3)_2CHCH(OH)CH_2OH$	**1**
(b)(iii)	optical (isomerism)	**1**
(b)(iv)	$C_5H_{12}O_2 + 3[O] \rightarrow C_5H_8O_3 + 2H_2O$	**1**
(c)(i)	Add bromine water / $Br_2(aq)$ **AND** turns (from orange / brown to) colourless	**1**
(c)(ii)		**1**
(d)(i)	3-methylbutan-1-ol	**1**
(d)(ii)	heterogeneous	**1**
(d)(iii)	**M1:** skeletal formula of Q  **M2: one** commercial use of Q (ethyl isovalerate / ethyl 3methylbutyrate) solvents / perfumes / flavourings	**2**
(e)(i)	1500–1680 (cm^{-1}) **AND** C=C	**1**
(e)(ii)	potassium cyanide / KCN / sodium cyanide / NaCN	**1**
(e)(iii)	(acidic) hydrolysis	**1**
(e)(iv)	**M1:** recognise this reaction involves less stable intermediate 1° (carbo)cation (intermediate) is less stable (than 3°) **M2:** explain difference in reactivity in terms of positive inductive effect – comparative answer low**er** (positive) inductive effect / lower (+)I **OR** inductive effect of **less** alkyl groups	**2**

168. 9701_m18_ms_22 Q: 4

(a)(i)	ultraviolet / UV light	**1**
(a)(ii)	initiation HC*l* propagation 	**4**
(b)	elimination	**1**
(c)(i)	acidified **AND** $KMnO_4$ hot **AND** c(oncentrated)	**2**
(c)(ii)	cyclohexene would have absorption at 1500–1680 (cm^{-1}) because of C=C (and adipic acid would not) cyclohexene would have absorption at 3000–3100 (cm^{-1}) because of =C—H/C—H in alkene (and adipic acid would not) adipic acid would have absorption at 2500–3000 (cm^{-1}) because of O—H/CO_2—H (and cyclohexene would not) adipic acid would have absorption at 1040–1300 (cm^{-1}) because of C—O (and cyclohexene would not) adipic acid would have absorption at 1640–1750 (cm^{-1}) because of C=O (and cyclohexene would not)	**max 3**

169. 9701_w18_ms_21 Q: 4

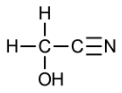
(a) — **4**

reagent	observation with glycolic acid	does a reaction occur? ✓ / ×	functional group
Na_2CO_3(aq)	effervescence / fizzing / bubbling	✓	COOH / carboxylic acid
2,4–DNPH	no visible reaction owtte	×	(no group required)
acidified $Cr_2O_7^{2-}$	orange to green	✓	–OH / alcohol

1 mark for each in column 2 (obs)

1 mark for COOH **and** OH

(b)(i) — **1**

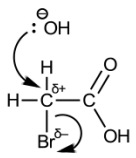


(b)(ii) — hydrochloric / sulfuric / nitric / phosphoric acid — **1**

(b)(iii) — free-radical substitution — **1**

(b)(iv) — UV (light) / sunlight — **1**

(b)(v) — **2**



M1 lone pair on $^-$OH **AND** curly arrow from lone pair to C of C—Br

M2 correct dipole on C—Br **AND** curly arrow from bond to Br

(c)(i) — reducing agent / reductant — **1**

(c)(ii) — **2**

$C_2H_2O_3 + 2[H] \rightarrow C_2H_4O_3$
M1 for correct molecular formulae $C_2H_2O_3$ and $C_2H_4O_3$
M2 for balancing

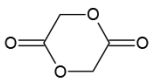
(d)(i) — **2**

EITHER
Glycolic acid would have:
M1 2500–3000 due to RCO_2-H
M2 range within 3200–3650 due to RO–H

OR

Spectrum Y would NOT have:
M1 2500–3000 due to RCO_2-H
M2 range within 3200–3650 due to RO–H

(d)(ii) — **2**

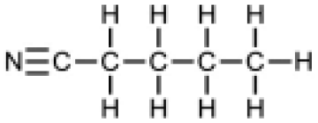
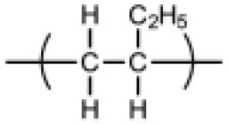
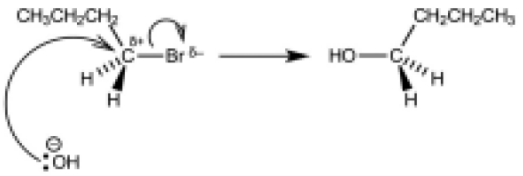
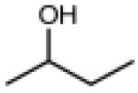
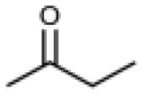


M1 ANY ester group **AND** valid $C_4H_4O_4$ molecule
M2 correct cyclic structure

170. 9701_w18_ms_22 Q: 3

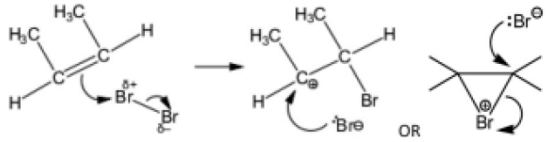
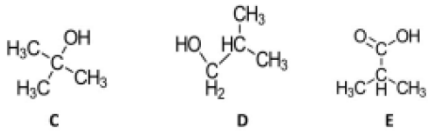
(a)	ΔH_r = (–692.9)+3(–61.8)- (–182.1) –3(–204.6) = –82.4 (kJ mol^{-1}) **M1** ΔH_r = x(–692.9) + y(–61.8) –v(–182.1) –w(–204.6) where x y v and w are integers ⩾1 [1] **M2** use of correct stoichiometry where x =1 y =3 v =1 and w=3 [1] **M3** –82.4 [1]	**3**
(b)(i)	1 mark for each bullet, max 3 • particles / molecules have (mass but) negligible size / volume (compared to total volume of gas / container) • no / negligible forces / interactions between particles / molecules • collision between particles / molecules are elastic • gas obeys (all) basic gas laws	**3**
(b)(ii)	**M1** particles / molecules are (so) close [1] **M2** particle / molecule size becomes significant [1] OR repulsive forces between particle / molecules become significant	**2**
(c)(i)	$CHCl_3 + ½O_2 \rightarrow COCl_2 + HCl$	**1**
(c)(ii)	**M1 X** marked on peak at 1670–1740 cm^{-1} [1] **M2** $CHCl_3$ has no C=O [1]	**2**
(c)(iii)	(It / $CHCl_3$ has a) peak at 2850–2950 (cm^{-1}) OR carbonyl dichloride spectrum has no peak 2850–2950 (cm^{-1})	**1**

171. 9701_m17_ms_22 Q: 3

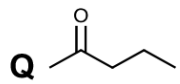
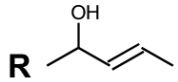
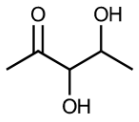
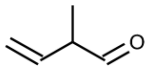
(a)(i)		**1**
(a)(ii)	reaction **1** = HC*l*(aq)	**1**
	reaction **2** = (conc.) NaOH / KOH **AND** ethanol	**1**
(a)(iii)	 C–C backbone with dangling bonds rest of structure	**2** 1 1
(b)	 lone pair on O **AND** curly arrow from O to C of C–Br dipole on C–Br **AND** curly arrow from C–Br to Br product (butan-1-ol)	**3** 1 1 1
(c)(i)	(electrophilic) addition	**1**
(c)(ii)	**S** has CH_3CHOH **OR** methyl / CH_3 group next to CHOH	**1**
(c)(iii)	positive inductive effect of more alkyl groups / more alkyl groups donate electron density	**1**
	secondary carbocation / secondary intermediate is more stable (than primary)	**1**
(c)(iv)	**S** = 	**1**
	T = 	**1**
	U = 	**1**
(c)(v)	$CH_3CHOHCH_2CH_3 + [O] \rightarrow CH_3COCH_2CH_3 + H_2O$	**1**
(d)(i)	methyl pentanoate	**1**
(d)(ii)	(compound **V** is) spectrum X	**1**
	spectra X and Z show a C=O (stretch) at 1730 (cm^{-1})	**1**
	spectra Y and Z show O–H (stretches) above 2500 (cm^{-1})	**1**
	V has a C=O (bond) and no O–H (bond)	**1**

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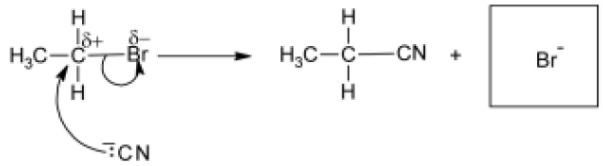
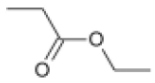
172. 9701_s17_ms_22 Q: 4

(a)(i)	(**A** =) 	**1**
(a)(ii)	(**A** / straight chain) has strong(er) (temporary dipole-) induced dipole (attractions) *ora*	**1**
	(because **A** / straight chain has) bigger (surface) area / more (points of) contact (in unbranched isomer) *ora* OR (so) more energy required to break the intermolecular forces *ora*	**1**
(a)(iii)	$CH_3CHCHCH_3$ OR $CH_3CH{=}CHCH_3$	**1**
(a)(iv)	No rotation / restricted / limited rotation of C=C / (carbon) double bond	**1**
	One (of the two) methyl groups / one (of the two) H (atoms) is on each C (of C=C)	**1**
(a)(v)	 arrow from the C=C double bond drawn to the bromine	**1**
	dipole on Br_2 in correct orientation AND arrow from the Br-Br bond to the $Br^{\delta-}$	**1**
	correct carbocation / bromonium ion from the structure with C=C drawn	**1**
	Br^- with lone pair, negative charge AND arrow from lone pair to the carbon atom of intermediate OR using both arrows shown (in alternative diagram)	**1**
(a)(vi)	electrons in pi bond induce it (the dipole) OR (high) electron density in pi bond / double bond / C=C repels electrons (away from nearest Br) OR polarised by (high) electron density in pi bond / double bond / C=C	**1**
(b)(i)	**C** = (2-)methylpropan-2-ol / $(CH_3)_3COH$ / any unambiguous structure	**1**
	D = (2-)methylpropan-1-ol / $(CH_3)_2CHCH_2OH$ / any unambiguous structure	**1**
	E = (2-)methylpropanoic acid /$(CH_3)_2CHCO_2H$ / any unambiguous structure  **C** **D** **E**	**1**
(b)(ii)	$2C_4H_8O_2 + Na_2CO_3 \rightarrow 2C_4H_7O_2Na + H_2O + CO_2$	**1**
(c)(i)	triiodomethane	**1**
(c)(ii)	**F** = $CH_3CH_2CH_2COCH_3$	**1**
	G = $C_2H_5CH(CH_3)CHO$	**1**
(c)(iii)	a (tetrahedral) atom with four different groups / atoms / substituents attached OR a carbon (atom) with four different groups / atoms / substituents attached	**1**
(d)(i)	**H** C=O (group / bond) AND O–H (group / bond)	**1**
	I C=O (group / bond) AND C–H (group / bond)	**1**
(d)(ii)	**H** = ethanoic acid	**1**
	I = methyl methanoate	**1**
	Total:	**23**

173. 9701_m16_ms_22 Q: 5

(a) (i)	**Q**  **R**  **S**  **T** 	[1] [1] [1] [1]
(ii)	pent-3-en(e)-2-one OR 3-penten-2-one	[1]
(iii)	red / orange / yellow precipitate / solid	[1]
(b)	*This question was discounted.* M1 = decolourises bromine / 1500–1600 cm^{-1} = alkene M2 = absorption at 1700 cm^{-1} is C=O AND (very) broad absorption at 2500–3000 cm^{-1} is O—H = carboxylic acid M3 = no cis-trans so terminal alkene OR chiral so contains a carbon atom with 4 different groups attached M4 = **U** is 	[1] [1] [1] [1]

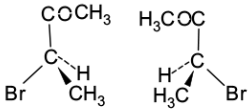
174. 9701_s16_ms_21 Q: 5

(a)	 M1 = lone pair on C of CN− AND curly arrow from lone pair to C of C—Br M2 = correct dipole on C—Br, curly arrow from C—Br bond to Br AND Br^-	[1] [1]
(b) (i)	reduction	[1]
(ii)	disappearance of peak / dip / trough / absorption at 1680–1730 due to (loss of) C=O OR peak at 3200–3650 due to (alcohol) O—H (formation)	[1] [1] [1] [1]
(c) (i)	sodium/potassium hydroxide aqueous	[1] [1]
(ii)	ethanol	[1]
(d) (i)	(conc) H^+ / (conc) acid / (conc)H_2SO_4 / (conc)H_3PO_4	[1]
(ii)		[1]
(iii)	ethyl propanoate	[1]
(e) (i)	**V** = $CH_3CH_2CHCHCH_2CH_3$ / $CH_3CH_2CH{=}CHCH_2CH_3$ **T** = $CH_3CH_2CH(OH)CH(OH)CH_2CH_3$	[1] [1]
(ii)	**V** = geometric(al) / *cis-trans* / *E–Z* **T** = optical	[1] [1]

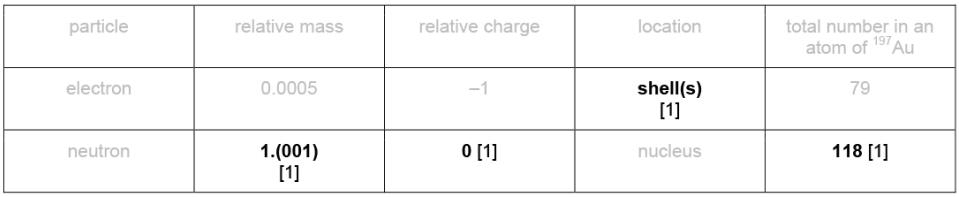
175. 9701_s16_ms_22 Q: 4

(a)	$CH_3CH_2CH_2COOH$ $(CH_3)_2CHCOOH$ / $CH_3CH(CH_3)COOH$	[1] [1]
(b) (i)	Two from 1. $CH_3CH_2COOCH_3$ 2. $CH_3COOCH_2CH_3$ 3. $HCOOCH_2CH_2CH_3$	[1] [1]
(ii)	correct acid + alcohol for either ester 1. methanol + propanoic acid 2. ethanol + ethanoic acid 3. propan-1-ol + methanoic acid (conc)H_2SO_4 / (conc)H_3PO_4 AND heat / warm / reflux	[1] [1]
(c)	Peak at 1710–1750 (for ester) due to C(=)O Peak at 1500–1680 (for **X**) due to C(=)C / alkene Peak at 3200–3650 (for **X**) due to (alcohol) O(–)H	[1] [1] [1]

176. 9701_s16_ms_23 Q: 4

(a)	3-hydroxybutan(-2-)one	[1]
(b)	H_2 / $Cr_2O_7^{2-}$ or names heat / reflux / warm	[1] [1]
(c) (i)	absorption at 1670–1740 C (=) O absorption at 2850–3000 C (-) H absorption at 3200–3650 O (-) H	[1] [1] [1]
(ii)	no absorption at 3200–3650 O-H disappears / no O-H bond in diacetyl	[1] [1]
(d) (i)	$CH_3COCH(=)CH_2$	[1]
(ii)	one of the double-bonded C atoms / first C has 2H atoms attached **ora** so no cis-trans / *E-Z* / geometric(al) isomerism possible OR no chiral C so mirror images superimposable / molecule not asymmetric	[1] [1]
(iii)	asymmetric / chiral C atom / carbon with four different groups / atoms attached	[1]
(iv)		[1+1]

177. 9701_w18_ms_22 Q: 1

(a)		**4**
(b)	metallic	**1**
(c)(i)	**M1** (atoms of the same element) with the same proton / atomic number [1] **M2** (but) different number of neutrons/mass number [1]	**2**
(c)(ii)	same number of electrons/electronic structure	**1**
(d)(i)	(100 – 56.36 – 25.14) = 18.5(0)	**1**
(d)(ii)	**M1** correct use of ^{63}Cu and ^{65}Cu and their % abundance [1] **M2** ÷ (56.36 + 25.14) **AND** answer correct to two decimal places [1]	**2**