

CHEMISTRY



EXAM QUESTION PACK

PAPER 2 ANSWERS (ALL TOPICS)

SCORE

/

PERCENTAGE

%

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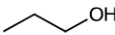
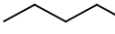
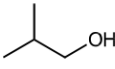
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Appendix A

Answers

1. 9701_s17_ms_21 Q: 1

(a)	The mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecules	1
	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)	1
(b)(i)	3	1
(b)(ii)	8	1
(b)(iii)	$\text{C}_3\text{H}_8\text{O} + 4\frac{1}{2}\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$	1
(b)(iv)	 OH AND propan-2-ol / 2-propanol	1
	 OH AND propan-1-ol / 1-propanol	1
	Alternative answers (any two):  OH AND butan-1-ol / 1-butanol	
	 OH AND butan-2-ol / 2-butanol	
	 OH AND (2-)methylpropan-1-ol / (2-)methyl-1-propanol	
(b)(v)	 OH AND (2-)methylpropan-2-ol / (2-)methyl-2-propanol	
	correct conversions of data to SI/consistent units $p = 100\,000$; $V = 20 \times 10^{-6}$; $T = 393$	1
	calculation of n ($= pV/RT$) from M1 values $n = \frac{100 \times 10^3 \times 20 \times 10^{-6}}{8.31 \times 393}$	1
	calculation of mass m ($= n \times Mr$) AND answer correct to 3sf $m = 6.12 \times 10^{-4} \times 60 = 0.0367$ (g) Alternative answer for using $\text{C}_4\text{H}_{10}\text{O}$: $m = 6.12 \times 10^{-4} \times 74 = 0.0453$ (g)	1
	Total:	10

2. 9701_m16_ms_22 Q: 2

(a) (i)	$\frac{27.30}{1000} \times 0.020 = 5.46 \times 10^{-4} \text{ (mol)}$	[1]
(ii)	$(i) \times 6 = 3.28 \times 10^{-3} \text{ (mol)}$	[1]
(iii)	$(ii) \times \frac{250}{25.00} = 3.28 \times 10^{-2} \text{ (mol)}$	[1]
(iv)	$M_r \text{ of FeCO}_3 = 55.8 + 12.0 + 3(16.0) = 115.8$ $(iii) \times M_r(\text{FeCO}_3) = 3.79 \text{ g}$	[1] [1]
(v)	$\frac{(iv)}{5.00} \times 100\% = 75.9\%$	[1]
(b) (i)	$2\text{Fe}^{3+} + \text{Sn}^{2+} \rightarrow 2\text{Fe}^{2+} + \text{Sn}^{4+}$ species balancing	[1] [1]
(ii)	$\text{SnCl}_2(\text{aq}) + 2\text{HgCl}_2(\text{aq}) \rightarrow \text{SnCl}_4(\text{aq}) + \text{Hg}_2\text{Cl}_2(\text{s})$ SnCl ₂ AND 2 state symbols	[1] [1]

3. 9701_w16_ms_21 Q: 1

(a)	$6 \times 10^{-3} \text{ (mol)}$	1	1
(b)	$\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$	1	1
(c)	$6 \times 10^{-3} \text{ (mol)}$	1	1
(d)	$4 \times 10^{-3} \text{ (mol)}$	1	1
(e)	$4 \times 10^{-3} \text{ (mol)}$	1	1
(f)	$1 \times 10^{-3} \text{ (mol)}$	1	1
(g)	170	1	1
(h)	28(.0) Si/silicon	1 1	2
		Total:	9

4. 9701_w16_ms_22 Q: 1

(a)	0.04 OR 4×10^{-2}	1
(b)(i)	$\text{Na}_2\text{CO}_3 + 2\text{HCl} \rightarrow 2\text{NaCl} + \text{CO}_2 + \text{H}_2\text{O}$	1
(b)(ii)	0.00075 OR 7.5×10^{-4}	1
(b)(iii)	0.0015 OR 1.5×10^{-3}	1
(b)(iv)	0.015 OR 1.5×10^{-2}	1
(b)(v)	0.025 OR 2.5×10^{-2}	1
(b)(vi)	0.0125 OR 1.25×10^{-2} OR 0.013 OR 1.3×10^{-2}	1
(b)(vii)	40 Ca / calcium	1 1
	Total:	9

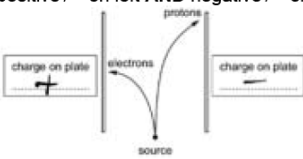
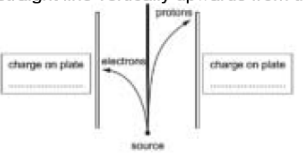
5. 9701_s17_ms_22 Q: 1

(a)	atomic number	nucleon number	number of electrons	number of protons	number of neutrons	symbol	2
		6		3	3		1
						$^{58}_{26}\text{Fe}^{3+}$	1
(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						2
(b)(ii)	$\frac{(10.0129 \times 19.78) + (80.22x)}{100} = 10.8$						1
	x = 10.9941						1
	Total:						6

6. 9701_s20_ms_23 Q: 2

(a)	EITHER M1 mass of an atom / isotope M2 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 M1 mass of one mol (of atoms) of an isotope M2 relative / compared to 1/12 (the mass) of 1 mol of C-12 OR in which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g		2
(b)	% abundance of ^{63}Cu = 72.5% % abundance of ^{65}Cu = 27.5% M1 correct algebraic expression AND correct calculation of x for one isotope % ab of ^{63}Cu = x $(x/100 \times 63) + ((1-x)/100 \times 65) = 63.55$ so x = 72.5 OR % ab of ^{65}Cu = x $(1-x)/100 \times 63 + x/100 \times 65 = 63.55$ so x = 27.5 M2 calculation of abundance of other isotope by 100- x		2
(c)(i)	metallic		1
(c)(ii)	diagram showing the bonding in a sample of copper  M1 diagram shows regular arrangement of spheres labelled as positively charged ions / +2 or +1 / cations M2 diagram shows surrounded by electrons and clearly labelled as 'delocalised electrons'		3
(c)(iii)	$(1s^2) 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ OR $(1s^2) 2s^2 2p^6 3s^2 3p^6 4s^1 3d^{10}$		1
(d)(i)	M1 calculate the number mol $\text{S}_2\text{O}_3^{2-}$ added $20/1000 \times 0.10 = 2 \times 10^{-3} = 0.002$ (mol $\text{S}_2\text{O}_3^{2-}$) M2 calculate number mol CuSO_4 in 250cm^3 $(1\text{mol } \text{S}_2\text{O}_3^{2-} : 1\text{mol } \text{CuSO}_4) = 0.002\text{mol } \text{CuSO}_4$ in 25cm^3 so 0.02 mol CuSO_4 in 250cm^3		2
(d)(ii)	M1 amount of CuSO_4 in 10.68 g of $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ M2 amount of H_2O in 10.68 g of $\text{CuSO}_4 \cdot x\text{H}_2\text{O}$ M3 value of x	$7.98 / (159.6) = 0.05$ (mol) $(10.68 - 7.98) / 18 = 2.7 / 18 = 0.15$ (mol) $(\text{mol } \text{H}_2\text{O} \div \text{mol } \text{CuSO}_4) = 3$	3

7. 9701_w20_ms_22 Q: 1

(a)(i)	positive / + on left AND negative / – on right 	1								
(a)(ii)	straight line vertically upwards from the source 	1								
(b)(i)	<table border="1"><tr><td>type of orbital</td><td>s</td><td>p</td><td>d</td></tr><tr><td>number of orbitals</td><td>4</td><td>9</td><td>5</td></tr></table>	type of orbital	s	p	d	number of orbitals	4	9	5	3
type of orbital	s	p	d							
number of orbitals	4	9	5							
(b)(ii)	4s ☐ 3p ☐ ☐ ☐ 3s ☐ ☐ 2p ☐ ☐ ☐ ☐ ☐ 2s ☐ ☐ 1s ☐ ☐	2								
(b)(iii)	5	1								
(b)(iv)	Award one mark for each correct bullet point – max 3 marks - nuclear charge increases - extra electron(s) in inner shell / $n=3$ / d-subshell / d- orbital - increased shielding (of 4s electrons by electrons in $n=3$ / 3rd shell / 3d) (overall) similar nuclear attraction (for outer electron)	3								
(c)	answer in terms of subatomic particles in the nucleus same (number of) protons AND different (number of) neutrons	1								

8. 9701_s19_ms_23 Q: 1

(a)(i)	All have the same nucleon number OR same sum / total number of protons + neutrons	1
(a)(ii)	(different) number of protons, neutrons and electrons	1
(b)	M1 $x / 100 \square 32 + (100 - x / 100 \square 34) = 32.09$ M2 $(32x + 3400 - 34x) = 3209$ so $x = 95.5$ M3 S^{32} 95.5% AND S^{34} 4.5%	3
(c)(i)	1s	1
(c)(ii)		1
(c)(iii)	M1 3p M2 It is less attracted to the nucleus (so takes less energy to lose) OR It is the highest energy orbital (which is occupied) / it is in the highest energy orbital	2
(d)(i)		1
(d)(ii)	M1 (in S, the electron is removed from the) 2 electrons in (3)p orbital OR a pair of electrons in (3)p (orbital / sub-shell) M2 (paired electrons) repel	2

9. 9701_s16_ms_21 Q: 1

(a)	name of element	nucleon no.	atomic no.	no. of protons	no. of neutrons	no. of electrons	overall charge	
	lithium	6	3	3	3	2	+1	[1]
	oxygen	17	8	8	9	10	−2	[1]
	iron	54	26	26	28	24	+2	[1]
	chlorine	35	17	17	18	17	0	[1]
(b)	line straight on labelled 'neutrons' line (curving) up labelled 'protons' proton line clearly shows less (overall) deflection than electron curve							[1] [1] [1]
(c) (i)	Group 16 / 6 / VI AND Big (owtte) increase / big difference / big gap / big jump / jump in increase / jump in difference after 6th IE							[1]
(ii)	increases (across period) due to increasing attraction (of nucleus for electrons) due to increasing nuclear charge / atomic / proton number AND constant / similar shielding / same (outer / number of) shell / energy level							[1] [1]
(iii)	electron (pair) repulsion (Y has a) pair of electrons in a (3)p orbital / a (3)p orbital is full ORA							[1] [1]
(iv)	(1s ²)2s ² 2p ⁶ 3s ² 3p ⁵							[1]
(d) (i)	0.56(%)							[1]
(ii)	$\frac{(A \times 0.56) + (86 \times 9.86) + (87 \times 7.00) + (88 \times 82.58)}{100} = 87.71$ A = 84							[1] [1]

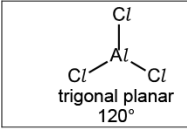
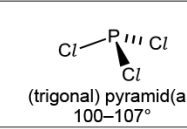
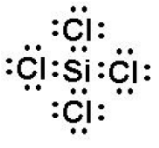
10. 9701_s16_ms_22 Q: 1

(a)	name of element	nucleon number	atomic number	number of protons	number of neutrons	number of electrons	overall charge	
	boron	10	5	5	5	5	0	[1]
	nitrogen	15	7	7	8	10	-3	[1]
	lead	208	82	82	126	80	+2	[1]
	lithium	6	3	3	3	2	+1	[1]
(b) (i)	Group 17/VII/7 AND big (owtte) increase/big difference/big gap/big jump/jump in increase/jump in difference after 7th IE							[1]
(ii)	increases across period due to increasing attraction (of nucleus for electrons) due to increasing nuclear charge/atomic/proton number AND constant/similar shielding/ same (outer) shell/energy level							[1] [1]
(iii)	$1s^2 2s^2 2p^6 3s^2 3p^4$							[1]
(c) (i)	$(100 - 99.76 - 0.04) = 0.2$							[1]
(ii)	$\frac{0.2x + (99.76 \times 16) + (0.04 \times 17)}{100} = 16.0044$ $x = 18$							[1] [1]

11. 9701_S15_ms_21 Q: 1

(a)	sub-atomic particle	relative mass	relative charge	
	neutron	1	0	[1]
	electron	1/1836	-1	[1]
	proton	1	+1	[1]
(b) (i)	RAM = mean/average mass of the isotopes/an atom(s) relative to 1/12 the mass of an atom of ^{12}C /on a scale where an atom of ^{12}C is (exactly) 12 (units)			[1]
	isotope = atoms with the same number of protons/atomic number/proton number with different mass numbers/numbers of neutrons/nucleon number			[1]
(ii)	$\frac{(0.89 \times 74) + (9.37 \times 76) + (7.63 \times 77) + (23.77 \times 78) + (49.61 \times 80) + (8.73 \times 82)}{100}$			[1]
	= 79.04 (2 d.p.) AND Se			[1]
(c) (i)	Te	Cl		
	$\frac{47.4}{128}$	$\frac{52.6}{35.5}$		[1]
	$\frac{0.370}{0.370}$	$\frac{1.48}{0.370}$		
	1	4	so EF = TeCl_4	[1]
	Empirical Formula Mass = 270 so MF = TeCl_4			[1]
(c) (ii)	Covalent AND simple/molecular			[1]
	low melting point/reaction with water			[1]
(iii)	$\text{TeCl}_4 + 3\text{H}_2\text{O} \rightarrow \text{H}_2\text{TeO}_3 + 4\text{HCl}$ OR $\text{TeCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{TeO}_2 + 4\text{HCl}$			[1]
(d) (i)	Yellow/orange flame			[1]
	White fumes/solid			[1]
	Yellow/green gas disappears			[1]
(ii)	NaCl giant/lattice AND ionic			[1]
	SiCl_4 simple/molecular AND covalent			[1]
	For NaCl large difference in electronegativity (of sodium/Na and chlorine/Cl/ Cl_2) (indicates electron transfer/ions)			[1]
	For SiCl_4 smaller difference (indicates sharing/covalency) with (weak) van der Waals'/IM forces (between molecules) ora			[1]

12. 9701_w17_ms_22 Q: 1

(a)	 trigonal planar 120°  (trigonal) pyramid(al) 100–107° 3 marking points for each box: diagram, name and shape. for each box: all three correct = 2 marks two correct = 1 mark	4
(b)(i)	SiCl ₄ simple / molecular AND Van der Waals' / id-id forces / London / dispersion forces / IMFs	1
	NaCl ionic OR giant	1
	bonding (in NaCl) stronger (than forces in SiCl ₄) owtte	1
(b)(ii)	SiCl ₄ has more electrons OR	1
	stronger Van der Waals' / id-id forces / London / dispersion forces / IMFs	1
(b)(iii)		1

13. 9701_s17_ms_21 Q: 2

(a)	substance	type of bonding	type of lattice structure	1
	copper	metallic	giant/metallic	
	ice	covalent OR hydrogen(-bonding) / H(-bonding)	hydrogen-bonded / simple / molecular	
	silicon(IV) oxide	covalent	giant (molecular) / macromolecular	
	iodine	covalent	simple / molecular	
	sodium chloride	ionic	giant / ionic	
(b)(i)	hydrogen bonding			1
(b)(ii)	H-bond between O and H of different molecules			1
	minimum three partial charges (in a row) over two H ₂ O molecules, i.e.: either $\delta^- \text{O} - \text{H}^{\delta+} \cdots \delta^- \text{O}$ or $\text{H}^{\delta+} \cdots \delta^- \text{O} - \text{H}^{\delta+}$			1
	lone pair of electrons on O of H-bond, in line with H-bond			1
(c)(i)	X = liquid AND Z = solid			1
	Y = liquid and solid OR 'liquid / solid' OR 'liquid OR solid'			1
(c)(ii)	(kinetic) energy reducing			1
	motion slowing owtte			1
(c)(iii)	energy given out / released forming bonds / forming bonds exothermic			1
	compensates for / counteracts heat loss / cooling owtte			1
	Total:			15

14. 9701_s16_ms_23 Q: 1

(a) (i)	$\text{Fe} + \text{H}_2\text{SO}_4 \rightarrow \text{FeSO}_4 + \text{H}_2$	[1]
(ii)	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 6\text{Fe}^{3+} + 7\text{H}_2\text{O}$	[1]
(iii)	$(0.025 \times 32.0/1000) = 8 \times 10^{-4}$	[1]
(iv)	$(8 \times 10^{-4} \times 6) = 4.8 \times 10^{-3}$	[1]
(v)	$(4.8 \times 10^{-3} \times 250/25.0) = 4.8 \times 10^{-2}$	[1]
(vi)	$(4.8 \times 10^{-2} \times 55.8) = 2.68/2.678$	[1]
(vii)	$(2.68/3.35) = 80\%$	[1]
(b) (i)	covalent small(er) difference in electronegativity between Fe and Cl (than between Al and Cl)	[1] [1]
(ii)	$\text{FeCl}_3 + 6\text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_6]^{3+} 3\text{Cl}^-$ OR $\text{FeCl}_3 + 6\text{H}_2\text{O} \rightarrow [\text{Fe}(\text{H}_2\text{O})_6\text{OH}]^{2+} + \text{H}^+ + 3\text{Cl}^-$	[1]

15. 9701_S15_ms_23 Q: 1

(a)	$(1s^2)2s^22p^6$	[1]
(b) (i)	The amount of energy required/energy change when one electron is removed from each atom in one mol of gaseous atoms	[1] [1] [1]
(ii)	Greater nuclear charge/number of protons Same shielding/number of shells/energy level	[1] [1]
(c) (i)	mean/average mass of the isotopes/an atom(s) relative to 1/12 of the mass of an atom of ^{12}C /on a scale where an atom of ^{12}C is (exactly) 12	[1] [1]
(ii)	$20.2 = \frac{(20 \times 90.48) + (21 \times 0.27) + (9.25y)}{100}$ $\frac{2020 - 1815.27}{9.25} = 22.133$ $y = 22$	[1] [1]
(d) (i)	$pV = \frac{mRT}{M_r}$ $M_r = \frac{mRT}{pV} = \frac{0.275 \times 8.31 \times 298}{100 \times 10^3 \times 200 \times 10^{-6}}$ $M_r = 34.05/34.1$	[1] [1]
(ii)	(Let % Ne = x so % Ar = 100-x) $\frac{20.2x + 39.9(100 - x)}{100} = 34.05$ % Ne = 29.7	[1]
(e) (i)	Van der Waal's/London/dispersion Uneven electron distribution/temporary dipole Induced dipole-dipole attraction	[1] [1] [1]
(ii)	more electrons more polarisable/greater attraction/stronger IMFs	[1] [1]

16. 9701_w15_ms_22 Q: 1

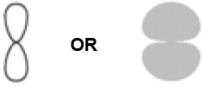
(a)	name of isotope	type of particle	charge	symbol	electron configuration	[5]
	carbon-13	atom	0	$^{13}_6\text{C}$	$1s^2 2s^2 2p^2$	
	chloride(-37)	anion	1-	Cl^-	$1s^2 2s^2 2p^6 3s^2 3p^6$	
	sulfur-34	atom	0	$^{34}_{16}\text{S}$	$1s^2 2s^2 2p^6 3s^2 3p^4$	
	iron-54	cation	2+	$^{54}_{26}\text{Fe}^{(2+)}$	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$	
(b) (i)	ability/tendency/power of an atom/nucleus to attract/pull electron(s)					[1]
	in a covalent bond/shared pair of electrons/bonding pair of electrons					[1]
(ii)	Covalent overlap of orbitals OR shared <u>pair(s)</u> (of electrons)					[1]
	OR metallic positive ions/cations surrounded by delocalised electrons					[1]
(iii)	Ionic/electrovalent (electrostatic) Attraction between oppositely charged/+ve and -ve <u>ions</u>					[1]
(c) (i)	similar strength/amount/number of intermolecular forces/induced dipole/van der Waals'/VdW/London forces/LDF/dispersion forces					[1]
	therefore similar energy needed					[1]
(ii)	M1 HCl polar/has a dipole AND F_2 non-polar/has no dipole OR (permanent) dipole (-dipole) attractions/forces between HCl (molecules) AND induced dipole (-induced dipole) attractions/forces/LDFs between F_2 (molecules)					[1]
	M2 more energy needed for HCl than F_2 OR pd-pd forces stronger than id-id forces OR IMFs/VdWs in HCl stronger than in F_2					[1]
(iii)	Hydrogen bonding (between methanol molecules)					[1]
	Stronger than IMFs/van der Waals' in other three/is the strongest intermolecular force					[1]

17. 9701_s21_ms_21 Q: 2

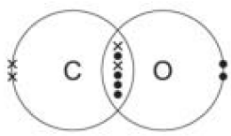
Question	Answer			Marks
(a)(i)	M1 both make triple (covalent) bond / 3 shared pairs of electrons			1
	M2 one bond in CO is coordinate / dative covalent / formed by donating a pair of electrons from O (to C)			1
(a)(ii)		N ₂	CO	2
	number of electrons per molecule	14	14	
	type of van der Waals'	temporary / instantaneous dipole-induced dipole	permanent dipoles—(permanent) dipoles (and temporary / induced / instantaneous dipoles)	
(b)	CO / it is a polar molecule / it has a (permanent) dipole (but N ₂ is non-polar)			1
(c)(i)	high temperature AND low pressure			1
(c)(ii)	M1 CO is polar / has a permanent dipole OR N ₂ is non-polar			1
	M2 IMF in CO are (more) significant / larger OR IMF in N ₂ are smaller / less significant			1
	<i>Alternative answer</i> M1 (Size of) N ₂ smaller than CO OR volume of N ₂ molecules / particles smaller			
	<i>Alternative answer</i> M2 volume of N ₂ molecules / particles is more negligible ORA			

Question	Answer			Marks
(d)	M1 correct conversion to consistent units P = 101 000 V = 100 / 1 000 000 = (1 × 10 ⁻⁴) T = 293			1
	M2 use of all values from M1 in correct relationship, n = PV / RT			1
	M3 calculation = 4.15 × 10 ⁻³ mol			1

18. 9701_s19_ms_21 Q: 3

(a)	$\text{Ar}^+(g) \rightarrow \text{Ar}^{2+}(g) + e^{-}$ OR $\text{Ar}^+(g) - e^{-} \rightarrow \text{Ar}^{2+}(g)$	1
(b)	at $x = 8$, within range 13000–20000	1
	at $x = 9$, within range 35000–45000	1
(c)		1
(d)(i)	M1 correct conversions of data to SI/consistent units $p = 404\,000$; $V = 20 \times 10^{-6}$; $T = 298$	1
	M2 calculation of n ($= pV/RT$) from M1 values $n = \frac{404000 \times 20 \times 10^{-6}}{8.31 \times 298} = 3.263 \times 10^{-3}$ mol of Cl_2	1
	M3 finding the mass of Cl_2 $= 3.263 \times 10^{-3} \times 71.0 = 0.23$ (g)	1
(d)(ii)	Method 1 M1 $= 3.263 \times 10^{-3} \times 2$ Method 2 M1 $= \frac{0.23}{71.0} \times 2$ OR 6.53×10^{-3}	1
	M2 $= 6.02 \times 10^{23} \times \text{M1}$ $= 3.93 \times 10^{21}$ atoms of Cl M2 $= 6.02 \times 10^{23} \times \text{M1}$ $= 3.90 \times 10^{21}$ atoms of Cl	1
(d)(iii)	M1 size / volume of molecule / particle becomes significant / non-negligible OR IMFs become significant / non-negligible	1
	M2 IMFs becomes significant / non-negligible / collisions are not elastic	1

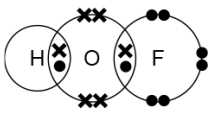
19. 9701_s21_ms_22 Q: 2

Question	Answer	Marks
(a)(i)	Li^+ AND S^{2-}	1
(a)(ii)	M1 giant	1
	M2 (many) strong force(s) of attraction between oppositely charged ions OR (many) strong ionic bond(s)	1
(b)(i)	(covalent) bond with both electrons are provided from the same / one species OR shared pair (of electrons) are provided from the same species / one atom <i>owtte</i>	1
(b)(ii)	3 bonding pairs between C and O, 4 $\bullet$'s AND 2 $\times$'s 1 lone pair on C, $\times\times$, AND 1 lone pair on O, $\bullet\bullet$. 	2

21. 9701_w15_ms_22 Q: 2

(a)	M1 <u>Heat</u> (energy) change (or $H_{\text{prod}} - H_{\text{react}}$) measured at constant pressure OR enthalpy change when the amount/moles of reactants as shown in a (reaction) <u>equation</u> react together to give products M2 measured at standard conditions	[1]
(b) (i)	$q = 2125.53$	[1]
(ii)	amount = 0.025(0)	[1]
(iii)	-85.(0)	[1]
(iv)	($\text{MgSO}_4(\text{s}) + 7\text{H}_2\text{O}(\text{l}) \rightarrow \text{MgSO}_4 \cdot 7\text{H}_2\text{O}(\text{s})$) $\swarrow$ $-85.0 \text{ (kJ mol}^{-1}\text{)}$ $\swarrow$ $(+)9.60 \text{ (kJ mol}^{-1}\text{)}$ $\text{MgSO}_4(\text{aq})$	[1]
(v)	$\Delta H + 9.6 = -85.0$ $\Delta H = -85.0 - 9.6 = -94.6 \text{ (kJ mol}^{-1}\text{)}$	[1]

22. 9701_m19_ms_22 Q: 2

(a)(i)	M1 ① mass of a molecule OR ② (weighted) average / mean mass of the molecules OR ③ mass of one mole of molecules M2 ① / ② compared to $\frac{1}{12}$ (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) ③ relative / compared to $\frac{1}{12}$ (the mass) of 1 mole of carbon-12 OR on a scale in which 1 mole of carbon-12 (atoms / isotope) has a mass of (exactly) 12 g	2
(a)(ii)	M1 identification of the IMF between F_2 molecules and between HCl molecules HCl has (permanent) dipoles and / or induced dipoles F_2 has induced dipoles M2 comparison of strength of IMF's in F_2 and HCl Intermolecular forces in HCl are stronger than F_2	2
(a)(iii)	strong (electrostatic) forces of attraction between (oppositely charged) ions	1
(a)(iv)	$CaCO_3(s) + 2HF(aq) \rightarrow CaF_2(aq) + CO_2(g) + H_2O(l)$ M1 species and balancing M2 state symbols	2
(b)(i)	$1s^2 2s^2 2p^6 3s^2 3p^6$	1
(b)(ii)	M1 purple gas / vapour disappears M2 iodine is not a strong enough oxidising agent ORA	2
(b)(iii)	M1 silver nitrate / $AgNO_3$ M2 yellow	2
(b)(iv)	(aqueous) ammonia / $NH_3(aq)$ / ammonium hydroxide / $NH_4OH(aq)$	1
(c)(i)	 M1 bonding pairs correct M2 rest of molecule, incl. lone pairs.	2
(c)(ii)	$F_2 + H_2O \rightarrow HF + HOF$	1
(c)(iii)	M1 labelled reactants AND products lower on right M2 labelled enthalpy change with correct arrow	2
(c)(iv)	$\delta^+ \quad \delta^- \quad \delta^+ \quad \delta^-$ $H-F \cdots H-F$ M1 H-bond labelled / shown as distinct from $H-F$ bond M2 correct sequence of three correct dipoles M3 lone pair on F in line with H-bond	3
(d)(i)	$pV = nRT \therefore n = \frac{pV}{RT} = \frac{101\,325 \times 0.001}{8.31 \times 273} = 0.0447 \text{ mol}$ $\therefore M_r = \frac{m}{n} = \frac{4.13}{0.0447} = 92.4 \text{ or } 92.5$ M1 Use of $T = 273 \text{ K}$, $V = 0.001 \text{ m}^3$ and $p = 101325 \text{ Pa}$ M2 correct use of $pV = nRT$ using values from M1 M3 correct calculation of M_r using $4.13 \div$ moles from M2	3
(d)(ii)	ClF_3	1

23. 9701_s20_ms_21 Q: 2

(a)(i)	$2\text{CuSO}_4(\text{aq}) + 4\text{KI}(\text{aq}) \rightarrow 2\text{CuI}(\text{s}) + (\text{+})\text{I}_2(\text{aq}) + 2\text{K}_2\text{SO}_4(\text{aq})$ M1 correct balancing M2 correct state symbols	2						
(a)(ii)	Oxidation state of copper in CuSO_4 (+)2 AND Oxidation state of copper in CuI (+)1	1						
(a)(iii)	M1 redox	1						
	M2 iodide ions – lost electron(s) AND copper ions – gained electron(s)	1						
(b)	<table><tr><td>Mass of 0.0982mol CuSO_4 in 17.43g $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$</td><td>M1 calculate M_r CuSO_4 using A_r from data booklet $63.5 + 32.1 + 64.0 = 159.6$ M2 use M_r to calculate mass of CuSO_4 $(0.0982 \times M1) = 15.67272\text{g}$</td></tr><tr><td>number of water in 17.43g of $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$</td><td>M3 calculate the mass amount of water in sample AND use this value to calculate the amount of water present $(17.43 - 15.67) / 18 = 0.097778 \text{ mol}$</td></tr><tr><td>value of y</td><td>M4 use the ratio of M2: 0.0982 to find y $(\text{mol H}_2\text{O} \div \text{mol CuSO}_4) = 1$</td></tr></table>	Mass of 0.0982mol CuSO_4 in 17.43g $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$	M1 calculate M_r CuSO_4 using A_r from data booklet $63.5 + 32.1 + 64.0 = 159.6$ M2 use M_r to calculate mass of CuSO_4 $(0.0982 \times M1) = 15.67272\text{g}$	number of water in 17.43g of $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$	M3 calculate the mass amount of water in sample AND use this value to calculate the amount of water present $(17.43 - 15.67) / 18 = 0.097778 \text{ mol}$	value of y	M4 use the ratio of M2: 0.0982 to find y $(\text{mol H}_2\text{O} \div \text{mol CuSO}_4) = 1$	4
Mass of 0.0982mol CuSO_4 in 17.43g $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$	M1 calculate M_r CuSO_4 using A_r from data booklet $63.5 + 32.1 + 64.0 = 159.6$ M2 use M_r to calculate mass of CuSO_4 $(0.0982 \times M1) = 15.67272\text{g}$							
number of water in 17.43g of $\text{CuSO}_4 \cdot y\text{H}_2\text{O}$	M3 calculate the mass amount of water in sample AND use this value to calculate the amount of water present $(17.43 - 15.67) / 18 = 0.097778 \text{ mol}$							
value of y	M4 use the ratio of M2: 0.0982 to find y $(\text{mol H}_2\text{O} \div \text{mol CuSO}_4) = 1$							

24. 9701_s19_ms_23 Q: 2

(a)(i)	held in regular / uniform arrangement	1
(a)(ii)	M1 covalent (bonds) AND (temporary) induced dipoles M2 (temporary) induced dipoles	2
(b)(i)	2	1
(b)(ii)	iodine (atom / s) donates a pair of electrons (to the A-I covalent bond / s).	1
(c)(i)	$2\text{H}_2\text{SO}_4 + 14\text{HI} \rightarrow 7\text{I}_2 + 8\text{H}_2\text{O} + \text{H}_2\text{S} + \text{S}$ M1 correct species M2 correctly balanced equation	2
(c)(ii)	<i>explain with ref to ox no's why the reaction in (c)(i) is a redox reaction</i> M1 I (oxidation number increases) from -1 to 0 = oxidation / reducing agent M2 S (oxidation number decreases) from (+) 6 to 0 OR -2 = reduction / oxidising agent	2

25. 9701_s16_ms_22 Q: 3

(a)	$\text{Cr}_2\text{O}_7^{2-} + 8\text{H}^+ + 3\text{H}_2\text{C}_2\text{O}_4 \rightarrow 2\text{Cr}^{3+} + 6\text{CO}_2 + 7\text{H}_2\text{O}$ M1 = species M2 = balancing	[1] [1]
(b) (i)	$(0.02 \times 32.0 / 1000) = 6.40 \times 10^{-4}$	[1]
(ii)	$(6.4 \times 10^{-4} \times 3) = 1.92 \times 10^{-3}$	[1]
(iii)	$(0.242 / 1.92 \times 10^{-3}) = 126(.0)$	[1]
(iv)	$(126 - 90 = 36; 36 / 18 = 2 \text{ hence}) x = 2$	[1]

26. 9701_s21_ms_23 Q: 2

Question	Answer	Marks
(a)	M1 H-bond between an O and an H in OH groups in water and methanol molecules	1
	M2 minimum three partial charges (in sequence) over one water and one methanol molecule, <i>i.e.</i> :	1
	M3 either $\delta^- \text{O} - \text{H}^{\delta+} - \delta^- \text{O}$ or $\text{H}^{\delta+} - \delta^- \text{O} - \text{H}^{\delta+}$ lone pair of electrons on O of H-bond, in line with H-bond	1
(b)(i)	M1 (methanol) gas (particles / molecules) in equilibrium with liquid	1
	M2 (methanol) gas (particles) exert a pressure (on the walls of a container / on the surface of the liquid)	1
(b)(ii)	(liquid) particles (at the surface) have enough energy (to overcome attractive forces / evaporate / to become a vapour)	1
(b)(iii)	M1 (liquid) H_2O molecules are held by stronger hydrogen bonding OR it takes more energy to break the hydrogen bonds between water molecules (in the liquid state) OR each water molecule forms two hydrogen bonds (whereas methanol can (only) form one per molecule)	1
	M2 fewer H_2O liquid molecules (able to) escape / become gaseous ora	1
(c)(i)	M1 rates of forward and reverse / backward reactions are equal	1
	M2 closed / sealed system / container OR no change in measurable properties / no change in macroscopic properties	1
(c)(ii)	M1 mol fraction = $0.97 / (0.030 + 0.060 + 0.97) = 0.97 / 1.06 = (0.9151)$	1
	M2 $M1 \times 1.0 \times 10^7 = 9.2 \times 10^6 \text{ (Pa)}$ ✓✓	1
(c)(iii)	<i>expression for K_p</i> M1 $K_p = p(\text{CH}_3\text{OH}) / p(\text{CO}) \times p(\text{H}_2)^2$	1
	M2 units = Pa^{-2}	1

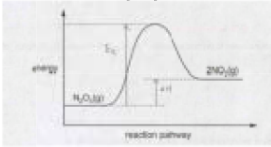
27. 9701_s18_ms_23 Q: 1

(a)	  trigonal planar non-linear/bent/V-shaped/angular	4
(b)(i)	stronger attraction for O ²⁻ / stronger ionic bonding / more energy needed to overcome ionic bonding / separate ions	1
	charge density of magnesium (ion) is greater (than sodium ion) <i>ora</i>	1
(b)(ii)	Either: M1 SiO₂ has a giant (covalent) structure / giant molecular M2 Covalent bonds (much) stronger than VdW / id-id / IMFs in SO₃ OR M1 SO₃ has a (simple) molecular structure / (simple) molecule. M2 VdW / id-id / IMFs M2 IMF's are (much) weaker than covalent bonds (broken in SiO₂) OR M1 Covalent bonds are broken in SiO₂ AND VdW / id-id / IMFs in SO₃ M2 Covalent bonds are stronger (than VdW / id-id / IMFs)	2
(c)(i)	molecules / particles / reacting species are closer together	1
	so frequency of collisions increases	1
	few(er) moles on right	1
	so (equilibrium) reaction shifts right / towards products / (as pressure increases to oppose the change)	1
(c)(ii)	Decreasing reactant concentrations (at different time intervals / as reaction progresses)	1
	So rate decreases OR change in concentration ÷ time taken decreases	1
(c)(iii)	(line becomes horizontal when) forward and reverse rates equal / equilibrium established	1
(c)(iv)	2:1 ratio in equation / SO ₂ used up more quickly (than O ₂) / 2 × SO ₂ react for every 1 × O ₂	1
(d)(i)	$K_c = \frac{[\text{SO}_3]^2}{[\text{SO}_2]^2 \times [\text{O}_2]}$	1
(d)(ii)	SO ₂ = 0.02 (mol)	1
	O ₂ = 1.01 (mol)	1
(d)(iii)	$K_c = \frac{(1.98 / 40)^2}{(0.02 / 40)^2 (1.01 / 40)}$ = 3.88 / 3.88 × 10⁵ Units = dm³ mol⁻¹ / mol⁻¹ dm³	M1 M2 M3

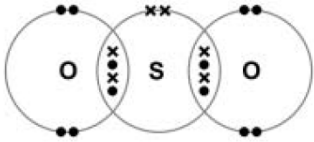
28. 9701_w17_ms_22 Q: 2

(a)	-444	1
(b)(i)	(higher rate / rate increases) due to higher frequency of successful collisions	1
	more molecules / particles with $E \geq E_a$	1
(b)(ii)	(percentage decomposition of PCl_5) increases	1
	(forward) reaction is endothermic	1
(c)	rates of forward and reverse / backward reactions are equal	1
	closed / sealed system/container	1
(d)(i)	$n_{\text{TOTAL}} = 1.20 + 0.80 + 0.80$ OR 2.80 (mol) OR mole fraction = $1.20 / 2.80$ OR 0.429	1
	$p\text{PCl}_5 = 1 \times 10^5 \times (1.20 / 2.80) = 4.29 \times 10^4 \text{ (Pa)}$	1
(d)(ii)	$K_p = \frac{p\text{PCl}_3 \times p\text{Cl}_2}{p\text{PCl}_5}$	1
(d)(iii)	1.91×10^4	1
	Pa	1

29. 9701_w16_ms_22 Q: 2

(a)	Arrow vertically up from N_2O_4 line to 2NO_2 line labelled enthalpy change / ΔH	1
	Arrow vertically up from N_2O_4 line to dashed line from peak labelled activation energy / E_a 	1
(b)(i)	$M_r = \frac{m \times R \times T}{p \times V} \left(= \frac{4.606 \times 8.31 \times 323}{1.68 \times 10^5 \times 1 \times 10^{-3}} \right)$ $= 73.6$	1 1
(b)(ii)	$2n$	1
(b)(iii)	$0.05 - n + 2n$ OR $0.05 + n$	1
(b)(iv)	$\frac{2n}{(0.05 + n)}$	1
(b)(v)	$\text{N}_2\text{O}_4 = 0.0375$ $\text{NO}_2 = 0.0250$	1 1
	$K_p = \frac{p\text{NO}_2^2}{p\text{N}_2\text{O}_4}$	1
(b)(vii)	$(0.4 \times 1.68 \times 10^5)^2 / (0.6 \times 1.68 \times 10^5)$ OR $0.4^2 \times 1.68 \times 10^5 / 0.6$	1
	44800 OR 44.8	1
	Pa OR kPa	1
Total:		13

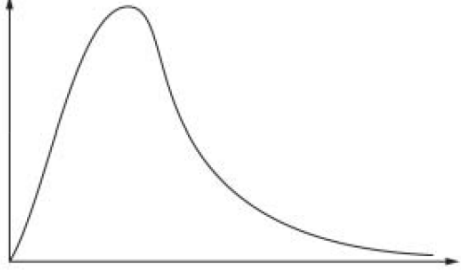
30. 9701_s18_ms_21 Q: 1

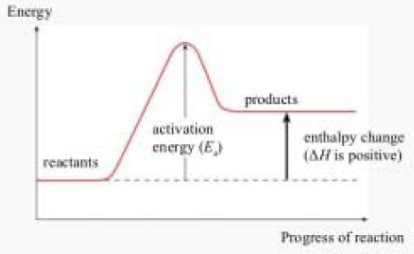
(a)(i)	(It is a substance that) speeds up a reaction	1
	(by creating an alternative pathway / mechanism with) lower E_a	1
(a)(ii)	(a heterogeneous catalyst is in a) different state / phase (to the reactants)	1
(b)	$-196 + 6S=O = (4 \times 534) + 496$	1
	$S=O = 2828 / 6 = 471(.3)$	1
(c)	1 = B	1
	2 = A	1
	3 = D	1
(d)(i)	Increases rate AND explanation re collisions	1
	By increasing number / proportion of / more molecules / particles / species with $E \geq E_a$	1
	(So) increases frequency of successful collisions / more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
(d)(ii)	(Increasing T) decreases yield (of SO_3)	1
	(Forward) reaction is exothermic (or reverse argument)	1
	So increasing T shifts (equilibrium) reaction to left / towards reactants / in endothermic direction (to oppose the change in T)	1
(e)	$H_2S_2O_7 + H_2O \rightarrow 2H_2SO_4$	1
(f)(i)		1
(f)(ii)	fully ionises/dissociates	1
	(Brønsted-Lowry acid is a) proton / H^+ donor	1
(f)(iii)	$H_2SO_4(l)/(aq) + H_2O(l) \rightarrow HSO_4^-(aq) + H_3O^+(aq)$	
	species and balancing	1
	correct state symbols on left hand side; all products aqueous	1

31. 9701_s18_ms_22 Q: 2

(a)	<i>option 1:</i> 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] <i>option 2:</i> 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)	<i>in any order explain meaning of:</i> <i>weak</i> partially ionises / incompletely dissociates (into ions) <i>Bronsted-Lowry acid</i> is a proton donor / H⁺ (ion) donor / hydrogen ion donor	2
c(ii)	NH ₄ ⁺ (aq) + H ₂ O(l) ⇌ NH ₃ (aq or g) + H ₃ O ⁺ (aq)	
	all correct species and balancing	1
	correct state symbols	1
(d)(i)	MnO ₄ ⁻ + 5Fe ²⁺ + 8H ⁺ → Mn ²⁺ + 5Fe ³⁺ + 4H ₂ O	1
(d)(ii)	(Fe²⁺ is a) reducing agent / reductant provides/donates electron(s) / loses electron(s) / increases its oxidation number / (Fe²⁺) becomes Fe³⁺	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

32. 9701_m21_ms_22 Q: 1

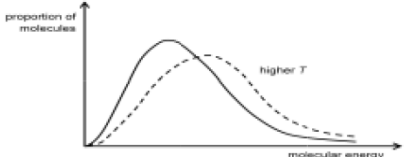
Question	Answer	Marks
(a)(i)	vertical axis: number of particles  horizontal axis: (kinetic / particle) energy M1: shape of curve correct M2: labelled axes	2
(a)(ii)	Labelled line (T2) with lower peak to right of original	1
(b)(i)	Any two from: - no VdW forces present / no forces of attraction between particles (ideal gas) particles have no / negligible volume (compared to container) - collisions between (ideal gas) particles / walls of container are perfectly elastic (ideal gas) particles behave as rigid spheres	2
(b)(ii)	M1: moles of krypton = $2.00 \div 83.8$ (= 0.0239 mol) M2: conversion of value into consistent units for $pV = nRT$ M3: $p = \frac{M1 \times 8.31 \times 393}{5.00 \times 10^{-3}} = 15600 \text{ Pa}$	3

Question	Answer	Marks
(b)(iii)	M1: low pressure AND high temperature M2: Either of: - volume of particles is negligible (compared to volume of container) - VdW forces are insignificant (owing to high kinetic energy of particles)	2
(c)(i)	 M1: end higher than start AND 'hill' for E_a M2: E_a AND ΔH labelled	2
(c)(ii)	- rate increases (increase in temperature means) more particles have energy $\geq$ activation energy - frequency of successful collisions increases	2

33. 9701_s17_ms_22 Q: 3

(a)	(+) 103	1
(b)(i)	general shape of the curve and peak are displaced to right of original and starts at origin	1
	the peak is lower and curve crosses once only finishing above original	1
(b)(ii)	rate increases AND correct explanation in terms of 'more collisions'	1
	at higher T area above E_a is greater / more molecules with $E \geq E_a$	1
	higher frequency of successful collisions OR more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
(b)(iii)	increases (%) decomposition (of HBr)	1
	(increasing T) shifts equilibrium to the right / in the forward direction / endothermic direction / towards $H_2 + Br_2$	1
	to oppose the change or oppose the increase in temperature OR to absorb (additional) energy / heat OR to decrease the temperature	1
(b)(iv)	H-I bond strength less than H-Br OR less energy needed to break H-I <i>ora</i>	1
	I (atom) is big(ger) (than Br) OR I (atom) has more shielding (than Br) <i>ora</i>	1
	Br (atom) has greater (%) orbital / outer shell overlap OR attraction (of nucleus in iodine) for shared (pair of) electrons is weak(er) OR attraction (of nucleus in iodine) for bonding pair (or electrons) is weak(er) <i>ora</i>	1
(c)(i)	$H_2 = 0.015$ (mol)	1
	$HCl = 0.27$ (mol)	1
(c)(ii)	$HCl = 9/10$ AND $xH_2 = 1/20$ AND $C_2 = 1/20$ OR $HCl = 0.9(0)$ AND $H_2 = 0.05$ AND $C_2 = 0.05$	1
(d)(i)	$(K_p =) \frac{pH_2 \times pCl_2}{pHCl^2}$	1
(d)(ii)	equal number of moles (of gas) on either side (of equation) / (total) pressure cancels	1
(d)(iii)	4.649×10^{-3}	1
Total:		18

34. 9701_w17_ms_21 Q: 1

(a)(i)	energy needed / required to break a mole of (covalent) bonds	1
	(All) in the gaseous state	1
(a)(ii)	$-92 = \{944 + 3(436)\} - 6E(\text{N-H})$	1
	$E(\text{N-H}) = (+)390.7 / 390.67 / 391$	1
(b)(i)	general shape of the curve and peak are displaced to right of original line and starts at origin	1
	the peak is lower and curve crosses once only finishing above original line	1
		
(b)(ii)	rate increases AND explanation in terms of collisions	1
	(at higher T) area above E_a is greater OR (at higher T) more molecules with $E \geq E_a$	1
	higher frequency of successful collisions OR more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
(b)(iii)	reduces yield (of ammonia).	1
	(increasing T) shifts equilibrium (reaction) to the left / in the reverse direction / towards N_2 and H_2 / towards reactants / in endothermic direction	1
	to oppose the change OR oppose the increase in temperature OR to absorb the (additional) heat / energy OR decrease the temperature	1
(c)(i)	$\text{N}_2 = 0.850 \text{ (mol)}$	1
	$\text{H}_2 = 2.55 \text{ (mol)}$	1
(c)(ii)	$n_{\text{TOTAL}} = 3.7 \text{ mol}$	1
	mol fraction of $\text{NH}_3 = 0.3 / 3.7$	1
	$p\text{NH}_3 = 2 \times 10^7 \times (0.3 / 3.7) = 1.62 \times 10^6$	1
(d)(i)	$K_p = \frac{p\text{NH}_3^2}{p\text{N}_2 \times p\text{H}_2^3}$	1
(d)(ii)	$K_p = 1.00 \times 10^{-16}$	1
	Pa^{-2}	1
(d)(iii)	(yield of ammonia) increases	1
	(value of K_p) stays the same	1

35. 9701_S15_ms_21 Q: 2

(a) (i)	Straight line drawn horizontally from same intercept	[1]
(ii)	T_1 because it shows greatest deviation/furthest from ideal	[1]
(iii)	reducing T (reduces KE of particles) so intermolecular forces of attraction become more significant	[1]
(iv)	greatest deviation is at high pressure increasing pressure decreases volume so volume of particles becomes more significant ora	[1] [1]
(b)	Mass of air = 100×0.00118 = 0.118 g Mass of flask = $47.930 - 0.118$ = 47.812 g Mass of Y = $47.989 - 47.812$ = 0.177 g $pV = nRT = \frac{m}{M_r} RT$ $M_r = \frac{mRT}{pV} = \frac{0.177 \times 8.31 \times 299}{1 \times 10^5 \times 100 \times 10^{-6}}$ = 44.0 (43.979 to 2 or more sf)	[1] [1] [1] [1]
(c) (i)	strong <u>triple</u> bond	[1]
(ii)	high temperature (needed for reaction between N_2 and O_2)	[1]
(iii)	$2NO + 2CO \rightarrow N_2 + 2CO_2$ OR $2NO + C \rightarrow N_2 + CO_2$	[1]
(iv)	$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$	[1]
(v)	$NO + \frac{1}{2}O_2 \rightarrow NO_2$ $NO_2 + SO_2 \rightarrow NO + SO_3$ OR $NO_2 + SO_2 + H_2O \rightarrow NO + H_2SO_4$	[1] [1]

36. 9701_s19_ms_21 Q: 2

(a)	M1 magnesium +2 charge on two Mg AND both with 0 or 8 electrons  OR 	1
	M2 silicide -4 charge on one Si and 8 electrons 	1
(b)	$\text{Mg}_2\text{Si(s)} + 4\text{H}_2\text{O(l)} \rightarrow 2\text{Mg(OH)}_2\text{(aq)} + \text{SiH}_4\text{(g)}$ M1 correct balancing and formulae	1
	M2 state symbols	1
(c)	M1 simple (covalent) / molecular / molecules	1
	M2 weak IMF / (temporary) induced dipole (forces)	1
(d)(i)	$\text{C}^{\delta-}-\text{H}^{\delta+}$	1
	$\text{Si}^{\delta+}-\text{H}^{\delta-}$	1
(d)(ii)	M1 tetrahedral (molecule)	1
	M2 (so individual bond) dipoles / partial charges cancel	1
(e)	M1 Si—H bond is (much) weaker than C—H bond	1
	M2 low activation energy <i>ORA</i>	1
(f)(i)	M1 sodium silicate / Na_2SiO_3	1
	M2 water / H_2O	1
(f)(ii)	acid(ic)	1

37. 9701_m18_ms_22 Q: 1

(a)(i)	☐ energy required / energy change ☐ when one electron is removed ☐ from each atom in one mole of ☐ gaseous atoms	max 3
(a)(ii)	<i>for element B</i> (outer electron is removed) from a higher energy level more shielding less attraction to nucleus	3
(b)	line on graph decreases P—T increasing nuclear charge AND electrons in same shell greater attraction between nucleus (and electrons)	3

38. 9701_w16_ms_22 Q: 3

(a)(i)	Increasing nuclear attraction	1
	Increasing nuclear charge / number of protons AND constant / similar shielding / same shell	1
(a)(ii)	From 12/Mg to 13/Al: (Outer) electron in '13'/Al in (3)p (whereas outer electron in '12'/Mg in (3)s) (3p =) higher energy level / more shielded	1
		1
	From 15/P to 16/S electron repulsion	1
	('16'/S has a) pair of electrons in a (3)p orbital / a (3)p orbital is full OR a	1
(a)(iii)	(decreasing IE down Group 0) due to decreasing nuclear attraction	1
	increasing shielding / increasing number of shells / energy levels / increasing distance of (outer) electrons (from nucleus)	1
(b)(i)	Increasing strength of / more energy needed to break (metallic) bonding / increasing strength of attraction between (cat)ion / nucleus and delocalised / free / sea of / cloud of electrons	1
	Increasing number of delocalised electrons / decreasing (cat)ion size / increasing charge / charge density of (cat)ion	1
(b)(ii)	Attraction for electrons too strong to fully delocalise all 3 in Al OR difference in size between 12/Mg ²⁺ and 13/Al ³⁺ is less than difference in size between 11/Na ⁺ and 12/Mg ²⁺ OR magnitude of increase in charge is less from 2+ to 3+ than from 1+ to 2+	1
(b)(iii)	Increase (15/P to 16/S) then decrease (to 17/Cl and 18/Ar) OR general decrease (from 15/P to 18/Ar) with an increase from 15/P to 16/S OR S ₍₈₎ > P ₍₄₎ > Cl ₍₂₎ > Ar	1
	(melting point depends on strength of) VdW / IMFs	1
	The greater the number of electrons in the molecule (atom for Ar) the greater the strength of VdW / IMFs OR the greater the melting point ora	1
(b)(iv)	Giant covalent (structure) / many (strong) covalent bonds (need breaking)	1
Total:		15

39. 9701_S15_ms_22 Q: 1

(a)	name of particle	relative mass	relative charge	
	proton	1	+1	[1]
	electron	1/1836	-1	[1]
	neutron	1	0	[1]
(b) (i)	Mass of an atom(s)			[1]
	relative to 1/12 th (the mass) of (an atom of) carbon-12 OR relative to carbon-12 which is (exactly) 12			[1]
(ii)	% of third isotope = 10			[1]
	$\frac{(24 \times 79) + (26 \times 11.0) + 10x}{100} = 24.3$			[1]
	10x = 248			
	x = 24.8 (3s.f.)			[1]
(c) (i)	anode	$2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^-$		[1]
	cathode	$\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg}$		[1]
(ii)	Mg	O	H	Cl
	31.65	20.84	1.31	46.2
	24.3	16	1	35.5
	1.30	1.30	1.31	1.30 = 1:1:1:1
	MgOHCl			
				[1]
(d) (i)	Na ₂ O basic/alkaline; Al ₂ O ₃ amphoteric/acidic and basic; SO ₃ acidic			[1]
	Na ₂ O (giant) ionic AND SO ₃ (simple/molecular) covalent			[1]
(ii)	Na ₂ O + 2HCl → 2NaCl + H ₂ O			[1]
	Al ₂ O ₃ + 6HCl → 2AlCl ₃ + 3H ₂ O			[1]
	Al ₂ O ₃ + 2NaOH + 7H ₂ O → 2NaAl(OH) ₄ (H ₂ O) ₂ OR			[1]
	Al ₂ O ₃ + 2NaOH + 3H ₂ O → 2NaAl(OH) ₄ OR			
	Al ₂ O ₃ + 2NaOH → 2NaAlO ₂ + H ₂ O OR			
	Al ₂ O ₃ + 2OH ⁻ + 7H ₂ O → 2[Al(OH) ₄ (H ₂ O) ₂] ⁻ OR			
	Al ₂ O ₃ + 2OH ⁻ + 3H ₂ O → 2[Al(OH) ₄] ⁻ OR			
	Al ₂ O ₃ + 2OH ⁻ → 2AlO ₂ ⁻ + H ₂ O			
	SO ₃ + NaOH → NaHSO ₄ OR			
	SO ₃ + 2NaOH → Na ₂ SO ₄ + H ₂ O			[1]

40. 9701_s20_ms_21 Q: 1

(a)(i)	(different) number of neutrons.	1
(a)(ii)	the relative abundance / % abundance of (each) the isotopes.	1
(b)(i)	M1 <i>attractions between atoms within a gallium trichloride molecule</i> covalent (bonds) M2 <i>attractions between gallium trichloride molecules</i> temporary induced dipoles	2
(b)(ii)	coordinate / dative (covalent)	1
(c)(i)	$4\text{Ga} + 3\text{O}_2 \rightarrow 2\text{Ga}_2\text{O}_3$ M1 correct formula of Ga_2O_3 M2 correctly balanced equation based on $\text{Ga} + \text{O}_2$ and formula of gallium oxide in M1	2
(c)(ii)	amphoteric	1

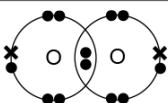
41. 9701_s20_ms_22 Q: 1

(a)	EITHER M1 (weighted) average/mean mass of the isotope(s)/an atom(s) M2 relative to 1/12 of the mass (of an atom) of ^{12}C (where an atom of ^{12}C is exactly 12). OR M1 mass of one mol of atoms M2 relative / compared to 1/12 (the mass) of 1 mol of C-12 OR in which one mol C-12 (atom) has a mass of (exactly) 12 g				2								
(b)	M1 $60.11/100 \times 69 + 39.89/100 \times 71$ M2 69.80				2								
(c)	<table border="1"> <tr> <td>isotope</td> <td>nucleon number</td> <td>total number of electrons in lowest energy level</td> <td>type of orbital contains the electron in the highest energy level</td> </tr> <tr> <td>^{71}Ga</td> <td>M1 71</td> <td>M2 2</td> <td>M3 p (-orbital)</td> </tr> </table>	isotope	nucleon number	total number of electrons in lowest energy level	type of orbital contains the electron in the highest energy level	^{71}Ga	M1 71	M2 2	M3 p (-orbital)				3
isotope	nucleon number	total number of electrons in lowest energy level	type of orbital contains the electron in the highest energy level										
^{71}Ga	M1 71	M2 2	M3 p (-orbital)										
(d)	M1 shape  M2 bond angle $120(^{\circ})$				2								
(e)(i)	$\text{Ga}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{GaCl}_3 + 3\text{H}_2\text{O}$				1								
(e)(ii)	M1 <i>Identity of correct gallium containing product</i> $\text{NaGa}(\text{OH})_4$ OR NaGaO_2 M2 <i>correctly balanced equation for reaction of Ga_2O_3 with $\text{NaOH}(\text{aq})$</i> EITHER $\text{Ga}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaGa}(\text{OH})_4$ OR $\text{Ga}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaGaO}_2 + \text{H}_2\text{O}$				2								

42. 9701_w19_ms_21 Q: 2

(a)	Na₂O	MgO	Al₂O₃	SiO₂	SO₃	2
	ionic	ionic	ionic	covalent	covalent	
	giant	giant	giant	giant / macro-molecular	simple / molecular	
	Award one mark for each correct row.					
(b)(i)	M1 SiO ₂ has a network of strong bonds / SiO ₂ has many strong bonds M2 SO ₃ has weak intermolecular forces OR weak VdW forces (between molecules) M3 high(er) / more energy required to break bonds than overcome forces (between molecules)					3
(b)(ii)	M1: reacts with both acid and base / alkali M2: use any equation with Al ₂ O ₃ and an acid, e.g. Al ₂ O ₃ + 6HCl → 2AlCl ₃ + 3H ₂ O M3: use any equation with Al ₂ O ₃ and a base / alkali, e.g. Al ₂ O ₃ + 2NaOH + 3H ₂ O → 2NaAl(OH) ₄					3
(b)(iii)	solid dissolves / disappears OR gets warm / hot					1
(c)(i)	octahedral					1
(c)(ii)	M1: use of the correct expression in terms of specific bond energies. (514 – xE _{Se–O} = –346) M2: use of correct stoichiometry AND correct processing of expression given in M1. Provided the values 514 and 346 are used. (514 – 2E _{Se–O} = –346) = (+)430 (kJ mol ^{–1})					2
(c)(iii)	SeO ₂ + 2NaOH → Na ₂ SeO ₃ + H ₂ O					1

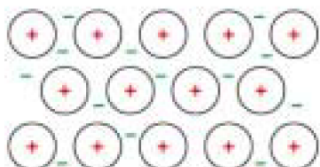
43. 9701_w19_ms_22 Q: 2

(a)	<table><tr><td>Na₂O</td><td>Al₂O₃</td><td>SiO₂</td><td>P₄O₁₀/P₄O₆/P₂O₃/P₂O₅</td><td>SO₃</td></tr><tr><td>basic</td><td>amphoteric</td><td>acidic</td><td>acidic</td><td>acidic</td></tr></table>	Na ₂ O	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀ /P ₄ O ₆ /P ₂ O ₃ /P ₂ O ₅	SO ₃	basic	amphoteric	acidic	acidic	acidic	2
	Na ₂ O	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀ /P ₄ O ₆ /P ₂ O ₃ /P ₂ O ₅	SO ₃							
	basic	amphoteric	acidic	acidic	acidic							
M1: all formulae correct M2: all acid / base behaviour correctly stated												
(b)(i)	reacts with both acid and base	1										
(b)(ii)	OH ⁻ + H ⁺ → H ₂ O	1										
(b)(iii)	reaction with strontium / reaction 1 will effervesce / fizz / bubble OR no fizzes / bubbles / effervescence with SrO	1										
(b)(iv)	increases	1										
(c)(i)	M1: correct conversion of quantities V = 5(.00) □ 10 ⁻⁴ (m ³) T = 293 (K) p = 5.37(0) □ 10 ³ (Pa) M2: calculation to find n using n = PV / RT (n) = 1.1 □ 10 ⁻³ (mol)	2										
(c)(ii)	(i) □ 78 = 0.0860 g	1										
(c)(iii)	 M1: bonding pair between the two O M2: total of 14 electrons distributed equally between the two O	2										

44. 9701_s18_ms_21 Q: 3

(a)(i)	increasing attraction between nucleus and (outer) electrons	1									
	increasing nuclear charge with similar shielding / (electrons in) same (outer) shell	1									
(a)(ii)	(ions of Na to Si have) lost outer shell / outer electrons OR atoms have one more shell than (corresponding) ions OR effective nuclear charge is greater for the ion	1									
(a)(iii)	(P to Cl form ions by) gaining electrons (to the same outer shell / p sub-shell)	1									
	Increased repulsion between electrons in same / outer shell / p sub-shell	1									
(b)(i)	(outer) electron removed from <u>3p</u> subshell / orbital	1									
	(3p) higher in energy / more shielded / further from the nucleus	1									
(b)(ii)	(outer) electron for S is paired in a <u>p orbital</u> / S has a full <u>p orbital</u>	1									
	causing (spin / electron) pair repulsion (which reduces attraction)	1									
(c)(i)	oxidation numbers / states of elements (Na-Si) increase from +1 to +4 / by 1 every time	1									
	increasing number of valence electrons / NaCl , MgCl_2 , AlCl_3 , SiCl_4 / number of chlorines matches group number	1									
	chlorine oxidation number / state -1 in all / stays the same	1									
(c)(ii)	$\text{NaCl} \rightarrow \text{Na}^+ + \text{Cl}^-$	1									
	$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$	1									
(c)(iii)	<table><tr><td></td><td>structure</td><td>bonding</td></tr><tr><td>sodium chloride</td><td>giant / ionic</td><td>ionic</td></tr><tr><td>silicon(IV) chloride</td><td>simple / molecular</td><td>covalent</td></tr></table>		structure	bonding	sodium chloride	giant / ionic	ionic	silicon(IV) chloride	simple / molecular	covalent	2
	structure	bonding									
sodium chloride	giant / ionic	ionic									
silicon(IV) chloride	simple / molecular	covalent									

45. 9701_m17_ms_22 Q: 1

(a)(i)	<table><tr><td>max O.N.</td><td>+1</td><td>(+2)</td><td>(+3)</td><td>(+5)</td><td>(+6)</td><td>+7</td></tr></table>	max O.N.	+1	(+2)	(+3)	(+5)	(+6)	+7	1
max O.N.	+1	(+2)	(+3)	(+5)	(+6)	+7			
(a)(ii)	(from Na to Cl) nuclear charge increases	1							
	electrons are in the same shell / have same shielding	1							
	greater / stronger attraction (of electrons to nucleus)	1							
(a)(iii)	Mg ²⁺ AND S ²⁻	1							
	ion of Mg / Mg ²⁺ has one fewer shell (than ion of S / S ²⁻)	1							
(b)(i)	P ₄ + 5O ₂ → P ₄ O ₁₀ / 2P ₂ O ₅	1							
(b)(ii)	any 2 from: • yellow / green colour (of chlorine gas) disappears • white flame • white solid • solid melts	2							
(b)(iii)	phosphoric(V) acid	1							
(c)(i)	 <u>diagram</u> showing regular arrangement of (positive) ions surrounded by / sea of (delocalised) electrons	2 1 1							
(c)(ii)	any 2 from: • high melting / boiling / sublimation point • electrical / thermal insulator • hard / rigid • retains strength at high temperature / pressure	2							
(c)(iii)	M1 % abundance of fourth isotope = 100 – (0.185 + 0.251 + 88.450) = 11.114	1							
	M2 $\frac{(0.185 \times 135.907) + (0.251 \times 137.906) + (88.450 \times 139.905) + (11.114 \times \text{RIM})}{100}$ = 140.116 ∴ (140.116 × 100) – 12434.35 = 1577.246 = 11.114 × RIM	1							
	M3 RIM = $\frac{1577.246}{11.114}$ = 141.915	1							

46. 9701_w17_ms_21 Q: 2

(a)(i)	due to increasing nuclear attraction (for electrons)	1
	due to increasing nuclear charge / atomic / proton number AND similar shielding / same (outer/number of) shell / energy level	1
(a)(ii)	Cross shown on first vertical line from the y-axis (Group 0 / Ne) is clearly higher than all shown	1
	Cross shown on second vertical line from the y-axis (Group 1 / Na) lower than all shown	1
(a)(iii)	Al (the outer / valence) electron (which is lost) is in (3)p sub-shell (Mg is in (3)s subshell) OR Al (the outer / valence) electron (which is lost) is in higher energy sub-shell	1 ora
	(electron to be removed) is more shielded / experiences greater screening effect	1 ora
	S has a pair of electrons in (a) (3)p orbital / (a 3)p orbital is full	1 ora
	electron pair repulsion	1
(b)(i)	(L=) MgCl_2 / magnesium chloride	1
	Any two from (giant) ionic (with strong attractions) $\text{Mg}^{2+}(\text{aq}) / \text{Mg}(\text{H}_2\text{O})_6^{2+}(\text{aq})$ is neutral / undergoes (partial) hydrolysis $\text{Mg}(\text{OH})_2$ is the white precipitate / solid / insoluble / partially soluble $\text{MgCl}_2 + 2\text{NaOH} \rightarrow \text{Mg}(\text{OH})_2 + 2\text{NaCl}$	2
(b)(ii)	(M=) SiCl_4 / silicon chloride	1
	Any two from (simple) molecular / simple covalent hydrolysis possible due to available d orbitals forms $\text{HCl}(\text{aq})$ / hydrochloric acid / solution and / or HCl gas / fumes white solid is (hydrated) SiO_2 $\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{HCl}$	2

47. 9701_w15_ms_21 Q: 1

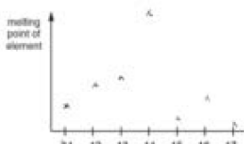
(a)	regular arrangement / lattice of cations / positive ions surrounded by delocalised electrons	[1] [1]
(b) (i)	electrical conductor corrosion resistant low density ductile malleable	[1] [1]
(ii)	Giant / lattice	[1]
(iii)	(electrical) insulator	[1]
(c) (i)	Simple covalent / covalent molecule Weak intermolecular forces / VdW forces OR little energy needed to break down / overcome intermolecular / VdW forces	[1] [1]
(ii)	$\begin{array}{cc} \text{Al} & \text{Cl} \\ 20.3 & 35.5 \\ 27 & 35.5 \end{array}$ $\begin{array}{cc} 0.752 & 2.25 \\ 0.752 & 0.752 \end{array}$ $\begin{array}{ccc} 1 & 3 & \text{AlCl}_3 \end{array}$	[1] [1]
(iii)	$pV = \frac{m}{M_r} RT \quad M_r = \frac{mRT}{pV} = \frac{1.36 \times 8.31 \times 473}{100 \times 10^{-3} \times 200 \times 10^{-6}} = 267$ OR $pV = nRT \quad n = \frac{pV}{RT} = \frac{100 \times 10^{-3} \times 200 \times 10^{-6}}{8.31 \times 473} = 5.09 \times 10^{-3}$ $M_r = \frac{1.36}{5.09 \times 10^{-3}} = 267$	[1] [1] [1] [1]
(iv)	Al_2Cl_6	[1]

48. 9701_s21_ms_23 Q: 3

Question	Answer				Marks
(a)(i)		state at room temp	observations on add'n of sample to water	identity of sample	4
	R	solid	alkaline, colourless solution is made but some white solid remains	M1 Ba(OH) ₂ OR barium hydroxide	
	S	solid	white solid disappears, solution is neutral	M2 NaCl OR sodium chloride	
	T	liquid	misty fumes, white solid is made in vigorous reaction	M3 SiCl ₄ OR silicon(IV) chloride	
	U	solid	acidic, colourless solution is made in vigorous reaction	M4 P ₄ O ₁₀ OR phosphorus(V) oxide	
(a)(ii)	SiO ₂				1
(a)(iii)	phosphoric acid / phosphoric(V) acid				1
(b)(i)	<i>any one physical property typical of ceramic materials from:</i> - strong / retain strength (over certain temperatures / conditions) - non-conductors of electricity / electrical insulators - high melting points				1
(b)(ii)	SiO ₂				1

Question	Answer	Marks
(c)	% of O M1 100 – 79.29 (= 20.71)	1
	M2 express W and O as mol by / 183.8 and / 16 respectively	1
	M3 divide each by smallest number to give empirical formula WO ₃	1

49. 9701_w21_ms_22 Q: 2

Question	Answer	Marks							
(a)(i)	<table border="1"><tr><td>M</td><td>M</td><td>M</td><td>C</td><td>C</td><td>C</td><td>C</td></tr></table>	M	M	M	C	C	C	C	1
M	M	M	C	C	C	C			
(a)(ii)	All 3 points correct scores two marks Any 2 points scores one mark <i>nuclear charge increases OR increasing proton number</i> e.g. 17 / Cl has a greater nuclear charge <i>describe the similarity in shielding between the two elements</i> e.g. they have almost the same shielding <i>describe the overall effect in terms of greater nuclear attraction for (outer) electrons</i> e.g. (outer) electrons are attracted more (strongly) to the nucleus	2							
(a)(iii)	M1 describes the difference between 1st IE of elements 15 and 16 (P and S) in terms of either: spin-pair repulsion (in element 16 / S) OR electron pair repulsion (in element 16 / S) M2 describes the location of the electron pair in the (3)p orbital which repel each other	2							
(a)(iv)	<table border="1"><tr><td>(+)1</td><td>(+)2</td><td>(+)3</td><td>(+)4</td><td>(+)5</td><td>(+)6</td></tr></table>	(+)1	(+)2	(+)3	(+)4	(+)5	(+)6	1	
(+)1	(+)2	(+)3	(+)4	(+)5	(+)6				
(a)(v)	M1 (anions have) same number of electrons (but increasing proton number) M2 increasing proton number / nuclear charge AND increasing attraction of nucleus for (outer) electrons OR (outer) electrons attracted more (strongly) to the nucleus AND because of increasing proton number / nuclear charge	2							
(b)		2							

Question	Answer	Marks
(c)	M1 density of ${}_{13}\text{Al}$: value within range 2.5–5.0 (g cm^{-3}) M2 cationic radius of ${}_{31}\text{Ga}$: value within range 0.055–0.075 (nm) M3 boiling point of ${}_{49}\text{In}$: value within range 1500–2300 (K)	3
(d)(i)	InCl_3	1
(d)(ii)	$\text{In}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaIn}(\text{OH})_4$	1
(d)(iii)	M1 correct connectivity of In_2Br_6 M2 showing the two correct dative covalent bonds	2

50. 9701_s16_ms_21 Q: 2

(a)	D = Ga G = Se	[1]
(b) (i)	$\text{D}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{DCl}_3 + 3\text{H}_2\text{O}$ M1 = species; M2 = balancing	[1] [1]
(ii)	$\text{D}_2\text{O}_3 + 2\text{NaOH} + 7\text{H}_2\text{O} \rightarrow 2\text{NaD}(\text{OH})_4(\text{H}_2\text{O})_2$ OR $\text{D}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaD}(\text{OH})_4$ OR $\text{D}_2\text{O}_3 + 2\text{NaOH} \rightarrow 2\text{NaDO}_2 + \text{H}_2\text{O}$ OR $\text{D}_2\text{O}_3 + 2\text{OH}^- + 7\text{H}_2\text{O} \rightarrow 2[\text{D}(\text{OH})_4(\text{H}_2\text{O})_2]^-$ OR $\text{D}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2[\text{D}(\text{OH})_4]^-$ OR $\text{D}_2\text{O}_3 + 2\text{OH}^- \rightarrow 2\text{DO}_2^- + \text{H}_2\text{O}$ M1 = species; M2 = balancing	[1] [1]
(c)	giant ionic / ionic lattice	[1]
(d)	$\text{GO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{GO}_3$	[1]

51. 9701_w20_ms_21 Q: 1

(a)	$\text{Mg}(\text{g}) \rightarrow \text{Mg}^+(\text{g}) + \text{e}^{(-)}$	1
(b)	M1: distance between nucleus and outer e⁻ increases OR outer electron removed from higher energy shell	3
	M2: increased shielding	
	M3: decreased nuclear attraction	
(c)	M1: greater nuclear attraction	2
	M2: (2nd / 2s) electron being removed from smaller (ion)	

52. 9701_w20_ms_22 Q: 2

(a)	more acidic / less basic (from Na to S across period)		1
(b)	M1: increases (from Na to S / across period)		2
	M2: increasing (number of) valence electrons OR (number of) electrons in outer (electron) shell increases		
(c)	reaction	name of product	2
	sodium oxide with water	sodium hydroxide	
	phosphorus(V) oxide with water	phosphoric(V) acid	
(d)	M1: <i>identification of forces broken during melting of phosphorus(V) oxide</i> intermolecular forces in phosphorus(V) oxide (are broken)		3
	M2: <i>identification of force broken during melting of magnesium oxide</i> electrostatic forces of attraction between (many oppositely charged) ions in magnesium oxide		
	M3: <i>statement linking difference in strength of appropriate forces described in M1 & M2 to explain difference in melting point</i> (only) intermolecular forces weaker than forces (of attraction) between ions / ionic bonds		
(e)(i)	$\text{Al}_2\text{O}_3 + 6\text{HCl} \rightarrow 2\text{AlCl}_3 + 3\text{H}_2\text{O}$		1
(e)(ii)	$\text{Al}_2\text{O}_3 + 2\text{NaOH} + 3\text{H}_2\text{O} \rightarrow 2\text{NaAl}(\text{OH})_4$		1
(f)	M1: giant		2
	M2: covalent AND tetrahedral / four Si—O bonds		
(g)(i)	$\text{Na}_2\text{O} + \text{SiO}_2 \rightarrow \text{Na}_2\text{SiO}_3$		1
(g)(ii)	$\text{Na}_2\text{CO}_3 \rightarrow \text{Na}_2\text{O} + \text{CO}_2$		1

53. 9701_s19_ms_21 Q: 1

(a)(i)	M1 (one) fewer (inner) shell of electrons / less shielding (effect) ORA	1
	M2 smaller distance of the outer electrons (from the nucleus) / stronger nuclear attraction to the (outer) electrons ORA	1
(a)(ii)	$\text{Sr(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Sr(OH)}_2\text{(aq)} + \text{H}_2\text{(g)}$	1
	M1 species AND balancing	
	M2 state symbols	1
(a)(iii)	M1 strontium AND forms a more soluble hydroxide	1
	M2 strontium hydroxide is a stronger base / produces more OH^- / it dissociates more	1
(a)(iv)	(white) solid dissolves / effervescence	1
(b)(i)	Similarities (any two from the following list) (both have) +2 ion / (+2) same oxidation state / same stoichiometry of oxide / <u>carbonates</u> decompose (on heating)	2
	Difference (X) forms coloured compounds/oxides/ carbonates OR Group 2 elements form white compounds/oxides/carbonates	1
(b)(ii)	XO	1
(b)(iii)	$\text{XCO}_3 \rightarrow \text{XO} + \text{CO}_2$	1

54. 9701_s19_ms_23 Q: 3

(a)	white light / flame AND (produces a) white / grey solid / ash / powder / smoke	1
(b)(i)	$\text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$	1
(b)(ii)	neutralisation	1
(c)	M1 giant (structure / lattice)	2
	M2 (so) lots of energy needed to break the bonds OR strong bonds	
(d)(i)	$\text{MgCO}_3\text{(s)} \rightarrow \text{MgO(s)} + \text{CO}_2\text{(g)}$	1
(d)(ii)	(thermal) decomposition	1

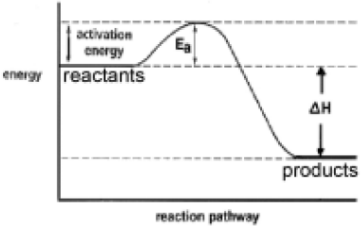
55. 9701_s18_ms_22 Q: 1

(a)(i)	$\text{Mg} + 2\text{H}_2\text{O} \rightarrow \text{Mg(OH)}_2 + \text{H}_2$	1
(a)(ii)	the product / Mg(OH)_2 sparingly soluble / slightly soluble / less soluble (than NaOH)	1
(b)(i)	any two from:	2
	• (from Mg to Ba) larger (atomic) radius / more shells / more shielding	
	• electron(s) are less tightly held (by nucleus) / less attracted (to nucleus)	
	• ionisation energy / ies decrease(s) / electron(s) lost (more) easily (down the group)	
(b)(ii)	white light / white flame	1
	white smoke / white solid	1
	$2\text{Mg(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{MgO(s)}$	1
(b)(iii)	$\text{Mg} + \text{H}_2\text{SO}_4 \rightarrow \text{MgSO}_4 + \text{H}_2$	1
(b)(iv)	any two from:	2
	• increasing (cation) size / (cat)ionic radius increases / increasing size of atoms • overall charge on (cation) is constant / (+)2 / decreasing charge density of (+2 charged cation) • number of delocalised / outer / valence electrons (per atom) remains the same / 2 • increased shielding	
	decreasing (strength of) attraction between (cat)ion / nucleus / nuclear charge AND delocalised electron(s)	1

56. 9701_m16_ms_22 Q: 1

(a) (i)	greater <u>attractive</u> force OR greater force <u>between nucleus and (outer) electrons</u> proton number/atomic number/nuclear charge increases across period AND electrons occupy same shell/shielding roughly constant	[1] [1]
(ii)	sulfur's electron removed from full (3p) <u>orbital</u> OR sulfur has two electrons in the same orbital electron–electron repulsion (reduces energy required)	[1] [1]
(iii)	sodium has mobile/free electrons/electrons free (to move throughout the structure) phosphorus is simple/covalent/molecular	[1] [1]
(iv)	magnesium has <u>two</u> free/delocalised/outer/valence electrons per atom OR <u>more</u> free/delocalised/ <u>outer</u> electrons than sodium	[1]
(b) (i)	A = $\text{Mg}(\text{NO}_3)_2$ B = H_2 C = NO_2 OR O_2 D = O_2 OR NO_2	[1] [1] [1] [1]
(ii)	any Group I carbonate OR ammonium carbonate	[1]

57. 9701_s16_ms_21 Q: 3

(a) (i)	bubbles/effervescence/fizzing calcium gets smaller/disappears water turns cloudy/milky calcium sinks	[1] [1] [1] [1]
(ii)	$\text{Ca} + 2\text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2 + \text{H}_2$	[1]
(iii)	faster bubbling/disappearance of Ba OR no/less precipitate forms (owtte)	[1]
(b) (i)	 M1 – general layout with products below reactants AND both labelled M2 – E_a and ΔH/energy change/released labelled with vertical lines	 [1] [1]
(ii)	activation energy is high so few/no particles with $E \geq E_a$	[1] [1]
(iii)	high melting/boiling point strong forces (of attraction/between oppositely charged ions)/ strong (ionic) bonding	[1] [1]
(iv)	MgO is basic / reacts with acid	[1]
(c) (i)	increases (down the group)	[1]
(ii)	$\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$	[1]
(iii)	$2\text{Ca(NO}_3)_2 \rightarrow 2\text{CaO} + 4\text{NO}_2 + \text{O}_2$	[1]

58. 9701_s20_ms_23 Q: 1

(a)(i)	M1 green flame / white flame (with green tinge) M2 white solid formed		2
(a)(ii)	$2\text{Ba(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{BaO(s)}$		1
(b)(i)	M1 heat (followed by) add water M2 $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ M3 $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$		3
(b)(ii)	thermal decomposition.		1
(b)(iii)	neutralise acid soil / reduce the acidity in soil / increase the pH in soil		1
(c)(i)	$4\text{Ga} + 3\text{O}_2 \rightarrow 2\text{Ga}_2\text{O}_3$		1
(c)(ii)	(+) ³		1
(c)(ii)	reagent and conditions	Formula of gallium containing product	2
	M1 gallium oxide+ hot HCl(aq)	M1 GaCl_3	
	M2 gallium oxide+hot concentrated NaOH(aq)	M2 NaGa(OH)_4 OR NaGaO_2	

59. 9701_s17_ms_21 Q: 3

(a)(i)	A	1
(a)(ii)	H	1
(a)(iii)	G	1
(a)(iv)	B	1
(a)(v)	F	1
(b)(i)	(strong) heating	1
	(to provide / overcome) <u>high</u> activation energy	1
(b)(ii)	<u>white</u> flame / <u>white</u> light / <u>white</u> smoke / <u>white</u> solid	1
(b)(iii)	$\text{Mg(s)} + 2\text{H}_2\text{O(l)} \rightarrow \text{Mg(OH)}_2\text{(s)} + \text{H}_2\text{(g)}$	2
(c)(i)	$2\text{Mg(NO}_3)_2 \rightarrow 2\text{MgO} + 4\text{NO}_2 + \text{O}_2$	1
(c)(ii)	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$	1
	$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$	1
(d)(i)	reduce acidity in soil / increase pH of soil	1
	(both) basic / base(s)	1
(d)(ii)	$\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$ OR $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{H}_2\text{CO}_3$	1
	Total:	16

60. 9701_w16_ms_21 Q: 3

(a)(i)	(Atoms/ ions become larger as) the number of (electron) shells increases (down the group) Increased distance of (outer) electrons (from the nucleus) OR Increased shielding results in weaker (nuclear) attraction / pull	1 1	2
(a)(ii)	top line / dotted line is atomic radii / bottom line / line with crosses is ionic radii (as atoms bigger than ions) Atom has one more shell (than corresponding ion) (ora) OR Atom loses two electrons / outer (shell) electrons / valency electrons (ora) OR Atom loses electrons and so (nuclear) attraction is stronger OR Nuclear charge in ion is greater than the electron(ic) charge (ora) OR Effective nuclear charge in ion is greater (ora)	1 1	2
(b)(i)	Nitrate / Nitrate(V) / NO_3^-	1	1
(b)(ii)	Ba / barium OR Sr / Strontium $\text{Ba}^{2+} + \text{SO}_4^{2-} \rightarrow \text{BaSO}_4$ OR $\text{Sr}^{2+} + \text{SO}_4^{2-} \rightarrow \text{SrSO}_4$	1	1
(b)(iii)	$\text{Ba}(\text{NO}_3)_2$ OR $\text{Sr}(\text{NO}_3)_2$ $2\text{Ba}(\text{NO}_3)_2 \rightarrow 2\text{BaO} + 4\text{NO}_2 + \text{O}_2$ OR $2\text{Sr}(\text{NO}_3)_2 \rightarrow 2\text{SrO} + 4\text{NO}_2 + \text{O}_2$	1 1	2
(c)(i)	$\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ OR $\text{Ca}(\text{OH})_2 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + 2\text{H}_2\text{O}$ $2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ OR $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$ OR $\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{HCO}_3^-$ OR $\text{CaCO}_3 + \text{H}^+ \rightarrow \text{Ca}^{2+} + \text{HCO}_3^-$	1 1	2
(c)(ii)	Calcium carbonate is insoluble / less soluble (ora) Calcium carbonate is less likely to be / won't get washed away (ora) OR Calcium carbonate lasts longer (ora) OR Calcium carbonate is less reactive / reacts more slowly (ora)	1 1	2
(d)	$\text{Mg}(\text{OH})_2$ MgO	1 1	2
Total:			14

61. 9701_S15_ms_23 Q: 2

(a) (i)	Reactivity increases down the group	[1]
	OR reference to observations that indicate trend	[1]
	Outer electrons lost more easily down group	[1]
	Due to increased distance/shielding of outer electrons from nucleus	[1]
(ii)	$\text{Mg} + 2\text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2 + \text{H}_2$	[1]
(iii)	Magnesium hydroxide sparingly soluble/insoluble	[1]
(iv)	$\text{Mg} + \text{H}_2\text{O} \rightarrow \text{MgO} + \text{H}_2$	[1]
(b) (i)	$\text{MgO} + 2\text{HNO}_3 \rightarrow \text{Mg}(\text{NO}_3)_2 + \text{H}_2\text{O}$	[1]
(ii)	(thermal stability) increases down the group	[1]
(iii)	$2\text{Mg}(\text{NO}_3)_2 \rightarrow 2\text{MgO} + 4\text{NO}_2 + \text{O}_2$	[1]
(iv)	N from (+)5 to (+)3	[1]
	O from -2 to 0	[1]
	N is reduced and O is oxidised	[1]
(c)	(Very) strong electrostatic attraction/ionic bond	[1]
	High charge (density) of cation and anion/ Mg^{2+} and O^{2-}	[1]
(d) (i)	$\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$	[1]
	$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2$	[1]
(ii)	$2\text{H}^+ + \text{CO}_3^{2-} \rightarrow \text{CO}_2 + \text{H}_2\text{O}$	[1]
(iii)	$1 \times 10^{-4} \times 8000 = 0.8 \text{ mol H}^+$	[1]
	$\frac{0.8}{2} \times 100.1 = \text{mass CaCO}_3 = 40 \text{ g}$	[1]

62. 9701_m17_ms_22 Q: 2

(a)(i)	bond in which the centres of positive and negative charges do not coincide OR electron distribution is asymmetric/unequal OR two (bonded) atoms are partially charged	1																									
(a)(ii)	HF has the strongest (permanent) dipole–dipole / van der Waals' (forces) / HF has hydrogen bonding	1																									
	requires more energy to overcome (than weaker (permanent) dipole–dipole / van der Waals' forces between other hydrogen halides)	1																									
(a)(iii)	thermal stability of the hydrogen halides decreases down group (17)	1																									
	larger (halogen) atoms / atomic radius (down group) / increased shielding	1																									
	bond energies decrease / less energy required to break H–X	1																									
(b)(i)	M1 base is Cl^- AND conjugate acid is HCl OR base is HSO_4^- AND conjugate acid is H_2SO_4	1																									
	M2 $\text{Cl}^- / \text{HSO}_4^-$ / base is a proton acceptor OR $\text{HCl} / \text{H}_2\text{SO}_4$ / (conjugate) acid has one more H^+	1																									
(b)(ii)	H_2SO_4 is (too strong) an oxidising agent	1																									
	I_2 would be formed instead	1																									
(c)(i)	$\Delta_r H = \Delta_r H\{\text{products}\} - \Delta_r H\{\text{reactants}\} = 2 \times (-242) - 4 \times (-92)$	1																									
	$= -116$ (sign AND answer)	1																									
(c)(ii)	heterogeneous (catalyst)	1																									
	provides an alternative reaction pathway of lower activation energy	1																									
(c)(iii)	reaction is exothermic	1																									
	(increased temperature) shifts equilibrium to the left AND decreases yield of products (Cl_2 and / or H_2O) / less product formed	1																									
(c)(iv)	<table><tr><td></td><td>HCl</td><td>O_2</td><td>Cl_2</td><td>H_2O</td></tr><tr><td>initial number of moles</td><td>1.60</td><td>0.500</td><td>0</td><td>0</td></tr><tr><td>M1 eqm number of moles</td><td>$1.60 - 2 \times 0.600 = 0.400$</td><td>$0.500 - \frac{1}{2} \times 0.600 = 0.200$</td><td>0.600</td><td>0.600</td></tr><tr><td>M2 mole fraction</td><td></td><td></td><td>$\frac{0.600}{1.80}$</td><td></td></tr><tr><td>M3 partial pressure</td><td></td><td></td><td>$\frac{0.600}{1.80} \times p_{\text{tot}} = 5.00 \times 10^4$</td><td></td></tr></table>		HCl	O_2	Cl_2	H_2O	initial number of moles	1.60	0.500	0	0	M1 eqm number of moles	$1.60 - 2 \times 0.600 = 0.400$	$0.500 - \frac{1}{2} \times 0.600 = 0.200$	0.600	0.600	M2 mole fraction			$\frac{0.600}{1.80}$		M3 partial pressure			$\frac{0.600}{1.80} \times p_{\text{tot}} = 5.00 \times 10^4$		3
	HCl	O_2	Cl_2	H_2O																							
initial number of moles	1.60	0.500	0	0																							
M1 eqm number of moles	$1.60 - 2 \times 0.600 = 0.400$	$0.500 - \frac{1}{2} \times 0.600 = 0.200$	0.600	0.600																							
M2 mole fraction			$\frac{0.600}{1.80}$																								
M3 partial pressure			$\frac{0.600}{1.80} \times p_{\text{tot}} = 5.00 \times 10^4$																								
(c)(v)	$K_p = \frac{(3.6 \times 10^4)^2 \times (3.6 \times 10^4)^2}{(4.8 \times 10^4)^4 \times 3.0 \times 10^4} = 1.05 \times 10^{-5}$	1																									
	units = Pa^{-1}	1																									
(c)(vi)	K_p would not change	1																									

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63. 9701_w17_ms_22 Q: 3

(a)	(IE) decreases / lower because increasing distance of outer electron(s) from nucleus OR increasing distance of outer / valence shell from nucleus OR increased shielding / screening (from inner shells)	1
	reduces nuclear attraction (for electrons)	1
(b)(i)	(Melting point) increases / higher because (molecules have an) increasing (number of) electrons	1
	increasing strength / number / amount of IMFs / Van der Waals' / id-id / London / dispersion (forces)	1
(b)(ii)	increased metallic / (cat)ionic radius / size OR decreasing (cat)ion charge-density	1
	decreased attraction (of ions) for delocalised / outer electrons	1
(c)(i)	reaction 1: HNO_3 or nitric(V) acid	1
	reaction 2: water / H_2O	1
(c)(ii)	barium oxide	1
	$2\text{Ba} + \text{O}_2 \rightarrow 2\text{BaO}$	1
(c)(iii)	NO_2 / nitrogen dioxide / nitrogen(IV) oxide AND O_2 / oxygen	1
	(red / yellow-)brown gas OR gas given off that relights glowing splint	1
(c)(iv)	<u>white</u> ppt / solid / suspension	1
	of BaSO_4 / barium sulfate OR $\text{Mg}(\text{OH})_2$ / magnesium hydroxide	1
	BaSO_4 is insoluble OR $\text{Mg}(\text{OH})_2$ is insoluble / partially / slightly / sparingly soluble	1

64. 9701_s19_ms_22 Q: 2

(a)	<i>trend in volatility down the group</i>	1
	decrease (in volatility)	
	<i>identification of specific IMF increasing</i>	1
	increasing (strength of) induced dipole (id) (interactions between molecules)	
(b)(i)	<i>explanation in terms of electrons</i>	1
	increasing number of electrons	
	<i>Conditions for reaction with Cl_2 at room temperature</i>	1
	ultra-violet / uv	
(b)(ii)	$\text{I}_2(\text{g} / \text{s}) + \text{H}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$	1
	M1 correctly balanced equation	
	M2 correct state symbols AND use of <u>equilibrium</u> sign	1
(c)(i)	proton / H^+ donor	1
(c)(ii)	acid HCl AND conjugate base Cl^-	1
(c)(iii)	co-ordinate / dative (covalent)	1
(c)(iv)	(triangular / trigonal) pyramid(al)	1
	$107^{(0)}$	1

65. 9701_s16_ms_22 Q: 2

(a) (i)	enthalpy/energy/heat change when one mole of <u>gaseous atoms</u> is produced	[1]
	from the element in its standard state	[1]
	under standard conditions	[1]
(ii)	fluorine and chlorine are gases/bromine liquid and iodine solid OR as ΔH_{at} for bromine/iodine also includes changes of state	[1]
(iii)	$(\frac{1}{2}\text{Cl}_2 + \frac{1}{2}\text{I}_2 \rightarrow \text{ICl})$ $\Delta H_f = (\frac{1}{2}E(\text{Cl}_2) + \frac{1}{2}E(\text{I}_2)) - E(\text{ICl})$ OR $E(\text{ICl}) = (151/2) + (242/2) + 24$	[1]
	$E(\text{ICl}) = (+) 220.5/221$	[1]
(b) (i)	stronger/more/greater id-id/London/dispersion forces	[1]
	due to increasing numbers of electrons	[1]
(ii)	(intermolecular forces in HF are) hydrogen bonds (which are) stronger (than vdW)/more energy needed to separate molecules	[1] [1]
	OR HF much more polar / F much more electronegative Intermolecular forces in HF stronger (than in HCl, HBr, HI)	[1] [1]
(c) (i)	P = iodine/I ₂ /I; Q = chlorine/Cl ₂ /Cl	[1]
(ii)	weaker H–P than H–Q bond ORA/easier/less energy to break H–P than H–Q ORA	[1]
	due to greater distance/shielding of nucleus from bond pair ORA	[1]
(iii)	2HP (or 2HI) $\rightarrow$ (or $\rightleftharpoons$) $\text{H}_2 + \text{P}_2$ (or I_2)	[1]
(iv)	$\text{Ag}^+(\text{aq}) + \text{Q}^-(\text{aq})$ (or Cl^-) $\rightarrow \text{AgQ}(\text{s})$ (or $\text{AgCl}(\text{s})$)	[1]
	$\text{AgQ}(\text{s})/\text{AgCl}(\text{s}) + 2\text{NH}_3(\text{aq}) \rightarrow \text{Ag}(\text{NH}_3)_2^+(\text{aq}) + \text{Q}^-(\text{aq})/\text{Cl}^-(\text{aq})$	[1]
(d) (i)	no of Cl increases <u>by one</u> each time/ matches group number	[1]
	due to increasing number of valence/outer(most/shell) electrons/oxidation number/valency (of Mg, Al, Si)	[1]
(ii)	$\text{MgCl}_2 + \text{aq} \rightarrow \text{Mg}^{2+} + 2\text{Cl}^-$	[1]
	$\text{AlCl}_3 + 6\text{H}_2\text{O} \rightarrow \text{Al}(\text{H}_2\text{O})_6^{3+} + 3\text{Cl}^-$ / $\text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+} + \text{H}^+ + 3\text{Cl}^-$	[1]
	$\text{SiCl}_4 + 2\text{H}_2\text{O} \rightarrow \text{SiO}_2 + 4\text{H}^+ + 4\text{Cl}^-$	[1]

66. 9701_s21_ms_21 Q: 3

Question	Answer	Marks
(a)(i)	$\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{NaHSO}_4 + \text{HCl}$ OR $2\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl}$	1
(a)(ii)	displacement / acid-base (reaction)	1
(b)(i)	hydrogen iodide / HI	1
	dark grey solid I ₂ / iodine	1
(b)(ii)	other product S / sulfur OR H ₂ S / hydrogen sulfide OR H ₂ O / water / steam	1
(c)	M1 iodide ions are strong(er) reducing agents (than chloride ions) ORA	1
	M2 HI / iodide is oxidised OR HCl / chloride is not oxidised	1
(d)	$2\text{Br}^- + 2\text{H}^+ + \text{H}_2\text{SO}_4 \rightarrow \text{Br}_2 + 2\text{H}_2\text{O} + \text{SO}_2$	1

67. 9701_s21_ms_22 Q: 1

Question	Answer	Mark
(a)	M1 cream	1
	M2 AgBr	1
(b)	(1) $\text{MBr}_2 + 2\text{AgNO}_3 \rightarrow 2\text{AgBr} + \text{M}(\text{NO}_3)_2$	1
(c)	M1 calculate M_r of MBr_2 using $8.415 \times 10^{-4} \text{ mol MBr}_2$ in 0.250 g $M_r = \dots\dots = 297(.1)\dots\dots$	1
	M2 calculate the atomic mass of M using M_r calculated in M1 $297.1 - (2 \times 79.9) = 137(.4)$	1
	M3 identify group 2 element from A_r in M2 Ba / barium	1
(d)(i)	(solution / mixture / liquid) turns (colourless to) orange or brown	1
(d)(ii)	displacement	1
(e)	M1 reagent: concentrated sulfuric acid	1
	M2 observation: brown vapour / gas (forms)	1
(f)(i)	explain how the action of heat is used to identify the 3 samples	1
	M1 nitrate AND carbonate lose mass / less than 1 g	
	M2 nitrate produces brown (NO_2) fumes	1
	M3 MgO no reaction / MgO no change	1
(f)(ii)	electronic configuration of Mg^{2+} ($1s^2$) $2s^2 2p^6$	1

Question	Answer	Mark
(g)	One similarity M1 solid(s) disappear(s)	1
	One difference M2 MgCO_3 fizzes (due to CO_2) OR no fizzing with $\text{Mg}(\text{OH})_2$	1

68. 9701_m20_ms_22 Q: 2

(a)	darker / stronger / deeper down the group	1
(b)(i)	weaker oxidising agents / (relative reactivity as oxidising agents) decreases down the group	1
(b)(ii)	M1 (structure =) simple / molecular, because it has a low melting / boiling point M2 (bonding =) covalent, because it is hydrolysed	2
(c)(i)	M1 cream ppt / solid M2 (ppt / solid) partially dissolves in (aqueous) ammonia	2
(c)(ii)	M1 <i>Acid behaviour of H₂SO₄</i> H ₂ SO ₄ acts as an acid with Cl ⁻ OR acid / base reaction with Cl ⁻ M2 <i>Oxidising behaviour of H₂SO₄</i> H ₂ SO ₄ acts as an oxidising agent with I ⁻ OR H ₂ SO ₄ does not oxidise Cl ⁻ M3 <i>Products formed</i> (for iodide reaction) I ₂ / S / SO ₂ / H ₂ S is formed OR (for chloride reaction) (only) HCl is formed OR <i>Comparison of oxidising strength</i> H ₂ SO ₄ not strong enough to / cannot oxidise Cl ⁻ (to Cl ₂) OR I ⁻ more powerful reducing agent than Cl ⁻	3
(d)(i)	M1 increases (down the group) because of increasing VdW M2 because of increasing number of electrons	2
(d)(ii)	M1 less stable (down the group) / decreases M2 lower H-Hal bond enthalpy / energy	2
(e)(i)	in the same phase / state	1
(e)(ii)	C ₂ H ₅ CH(OH)C ₂ H ₅ + HCl → C ₂ H ₅ CH(Cl)C ₂ H ₅ + H ₂ O	1
(e)(iii)	$ \begin{array}{c} \text{OH} \\ \\ \text{H}_3\text{C}-\text{C}-\text{CH}_2\text{CH}_3 \\ \\ \text{CH}_3 \end{array} $	1
(e)(iv)	substitution	1

69. 9701_s17_ms_23 Q: 2

(a)(i)	halogen	colour	state	2
	chlorine	yellow / green	gas	
	bromine	red / brown / orange	liquid	
	iodine	grey / black	solid	
(a)(ii)	increasing number of electrons			1
	(gives) increasing strength of van der Waals' / id-id forces / London / dispersion forces			1
(b)	oxidising power decreases down the group.		ora	1
	ability to accept electrons decreases (down the group)		ora	1
	because (outer shell experiences) more shielding OR increased distance from nucleus (to outer shell) (outweighs the increasing nuclear charge down the group)		ora	1
(c)(i)	solid sodium chloride: steamy / misty / white fumes			1
	solid sodium iodide: purple fumes			1
(c)(ii)	(conc sulfuric) not powerful enough oxidising agent (to oxidise chloride) OR chloride not powerful enough reducing agent (to reduce sulfuric acid)			1
	iodide reduces sulfuric acid OR iodide / I ⁻ is oxidised OR sulfuric acid oxidises iodide			1
(c)(iii)	2NaBr + 2H ₂ SO ₄ → Br ₂ + SO ₂ + Na ₂ SO ₄ + 2H ₂ O OR NaBr + H ₂ SO ₄ → NaHSO ₄ + HBr AND 2HBr + H ₂ SO ₄ → Br ₂ + SO ₂ + 2H ₂ O OR 2NaBr + H ₂ SO ₄ → Na ₂ SO ₄ + 2HBr AND 2HBr + H ₂ SO ₄ → Br ₂ + SO ₂ + 2H ₂ O			2
(d)(i)	AgI (and AgCl solid) / silver ions reacting with iodide ions			1
(d)(ii)	AgCl (precipitate) dissolves (in ammonia)			

70. 9701_s21_ms_23 Q: 1

Question	Answer	Marks
(a)(i)	increases	1
(a)(ii)	chlorine gas bromine liquid iodine solid	1
(b)	M1 observation with $\text{Cl}_2(\text{aq})$ (colourless / pale green to) orange / brown	1
	M2 observation with $\text{I}_2(\text{aq})$ no visible change	1
	M3 explanation chlorine is a stronger oxidising agent (than bromine) AND iodine is a weaker oxidising agent	1
(c)	$\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$	1
(d)(i)	proton / H^+ acceptor	1
(d)(ii)	$\text{ClO}^- + \text{H}_2\text{O} \rightarrow \text{HClO} + \text{OH}^-$	1
(e)	M1 Use volume O_2 to express / find no mol O_2 produced $24 / 24\,000 \text{ mol O}_2 \text{ produced} = 1 \times 10^{-3} \text{ (mol)}$	1
	M2 Use 1:1 ratio to deduce no mol NaClO in 1000 cm^3 sample $\text{M1} \times 1000 / 5 = 0.2 \text{ (mol dm}^{-3}\text{)}$	1
	M3 Use amount of NaClO and its molecular mass (74.5) to find the mass of NaClO added $24 / 24\,000 \times 1000 / 5 \times 74.5 = 14.9 \text{ (g dm}^{-3}\text{)}$	1
(f)	M1 products contain Cl^- AND Cl_2	1
	M2 correct balanced equation $\text{ClO}^- + 2\text{HCl} \rightarrow \text{Cl}^- + \text{H}_2\text{O} + \text{Cl}_2$	1

71. 9701_s18_ms_23 Q: 3

(a)(i)	(volatility) decreases	1
(a)(ii)	increasing numbers / more of electrons (in molecules)	1
	increased strength of id-id / VdW / IMFs	1
(b)	$\text{Cl}_2 + 2\text{NaI} \rightarrow 2\text{NaCl} + \text{I}_2$	1
(c)(i)		3
(c)(ii)	$\text{Ag}^+(\text{aq}) + \text{I}^-(\text{aq}) \rightarrow \text{AgI}(\text{s})$	1
(d)	M1 sulfuric acid acts as an acid with NaCl (and NaBr) OR $\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{NaHSO}_4 + \text{HCl}$ OR $2\text{NaCl} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{HCl}$	1
	sulfuric acid acts as an oxidising agent with NaI / I OR NaI is a reducing agent	1
	I ⁻ more powerful reducing agent than Cl ⁻ OR sulfuric acid can oxidise I ⁻ but not Cl ⁻ OR sulfuric acid is a stronger oxidising agent than iodide ions OR sulfuric acid is not as strong an oxidising agent than chloride ions	1
(e)(i)	(Species that) gains <u>electrons</u> / <u>electron</u> acceptor	1
(e)(ii)	$\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{HClO}$	1
(e)(iii)	$3\text{Cl}_2 + 6\text{NaOH} \rightarrow 5\text{NaCl} + \text{NaClO}_3 + 3\text{H}_2\text{O}$	1
	0 to -1 (+)5 AND chlorine has been oxidised and reduced.	1

72. 9701_s19_ms_22 Q: 3

(a)(i)	$\text{SiCl}_4(l) + 2\text{H}_2\text{O}(l) \rightarrow \text{SiO}_2(s) + 4\text{HCl}(aq / g)$ (state symbols required)	1								
(a)(ii)	hydrolysis	1								
(a)(iii)	NaCl – ionic	1								
	SiCl ₄ – covalent	1								
(a)(iv)	M1 statement correctly comparing the difference in electronegativity between Si and Cl AND Na and Cl OR Na is less electronegative than Si OR A	1								
	M2 NaCl transfer of electrons	1								
	M3 SiCl ₄ shared (pair of) electrons	1								
(b)(i)	<table border="1"><tr><td>Chlorine containing species</td><td>Cl₂</td><td>HCl</td><td>HOCl</td></tr><tr><td>Oxidation number of chlorine</td><td>0</td><td>-1</td><td>(+)1</td></tr></table>	Chlorine containing species	Cl ₂	HCl	HOCl	Oxidation number of chlorine	0	-1	(+)1	2
	Chlorine containing species	Cl ₂	HCl	HOCl						
Oxidation number of chlorine	0	-1	(+)1							
	Award 2 marks for 3 correct oxidation numbers Award 1 Mark for 2 correct oxidation numbers									
(b)(ii)	disproportionation	1								
(b)(iii)	kills micro-organisms	1								
(c)	$2\text{NaOH} + \text{HCl} + \text{HClO} \rightarrow \text{NaCl} + \text{NaClO} + 2\text{H}_2\text{O}$ M1 Identifies the product NaClO M2 Correctly balances the equation OR The overall equation may be seen as: $\text{NaOH} + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O}$ AND $\text{NaOH} + \text{HClO} \rightarrow \text{NaClO} + \text{H}_2\text{O}$	2								

73. 9701_s20_ms_21 Q: 3

(a)	M1 (enthalpy / energy change) when one mole of a compound/substance is formed M2 from its elements in their standard states	2
(b)	M1 <i>use of correct stoichiometry in calculation</i> $3 \times \Delta H_f^\circ \text{NO}_2 - 1 \times \Delta H_f^\circ \text{H}_2\text{O} - 2 \times \Delta H_f^\circ \text{HNO}_3 - 1 \times \Delta H_f^\circ \text{NO}$ M2 <i>correct signs associated with the appropriate ΔH_f° values/terms used for the calculation of $\Delta H_{\text{reaction}}$</i> M3 $\Delta H_{\text{reaction}} = -(102 - 286) + (-346 + 91.1) = -70.9 \text{ kJ mol}^{-1}$	3
(c)	M1 nitrogen has a triple bond M2 EITHER high energy is needed to break the bond OR at normal temperatures there is not enough energy to break the bond / to overcome the activation energy	2
(d)	lightning	1
(e)(i)	M1 <i>define homogeneous</i> (homogeneous catalyst is) in the same phase / state as the reactants M2 and M3 <i>Define catalyst</i> All 3 points scores 2 marks. Any 2 points scores 1 mark increase the rate AND lowers the activation energy AND without being chemically altered at the end of the reaction / are regenerated at the end of the reaction	
(e)(ii)	M1 $\text{NO}_2 + \text{SO}_2 \rightarrow \text{NO} + \text{SO}_3$ M2 $\text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2$	2

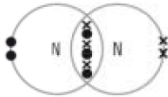
74. 9701_s20_ms_21 Q: 4

(a)	Accepts a proton / H ⁺ (ion)	1												
(b)	Two reasons why product mixture is added to soil – allow in any order M1 Acts as a fertiliser / adds nutrients (for plants) M2 Neutralise acid soils / increases the pH of acid soil	2												
(c)	<table border="1"> <thead> <tr> <th></th><th>name of shape</th><th>bond angle / °</th></tr> </thead> <tbody> <tr> <td>CO₂</td><td>Linear</td><td>180</td></tr> <tr> <td>NH₃</td><td>Pyramid(al)</td><td>107</td></tr> <tr> <td>H₂O</td><td>non-linear / V / bent</td><td>104.5</td></tr> </tbody> </table> All 6 correct – 3 marks 4 or 5 correct – 2 marks 2 or 3 correct – 1 mark		name of shape	bond angle / °	CO ₂	Linear	180	NH ₃	Pyramid(al)	107	H ₂ O	non-linear / V / bent	104.5	3
	name of shape	bond angle / °												
CO ₂	Linear	180												
NH ₃	Pyramid(al)	107												
H ₂ O	non-linear / V / bent	104.5												

75. 9701_s20_ms_22 Q: 2

(a)	$4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$	1
(b)	$\begin{array}{c} \text{xx} \\ \text{H} \times \text{N} \times \text{H} \\ \text{xO} \\ \text{H} \end{array}$	1
(c)(i)	$3\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_3 + \text{NO}$ (+)4 (+)5 (+)2 3 correct oxidation numbers – 2 marks 2 correct oxidation numbers – 1 mark	2
(c)(ii)	relates the term disproportionation to the reaction described M1 nitrogen /N (in nitrogen dioxide) is both gaining electrons and losing electrons during the reaction M2 refer to relevant transfer of electrons when NO₂ reacts to form HNO₃ and NO NO₂ to HNO₃ involves loss of electron(s) AND NO₂ to NO involves gain of electron(s)	
(d)	M1 state the effect of NO gas on contact with moist air NO reacts with water OR NO reacts with oxygen and water. M2 consequence of M1 in terms of atmospheric pollution causing acid rain OR photochemical smog / ground level ozone OR destroy ozone layer	2
(e)	M1 number of mol in sample of NH₄NO₃ 40t NH₄NO₃ = 500 000 mol ammonium nitrate M2 ratio of mol NO₂: NH₄NO₃ 3/2 mol NO₂:1 mol NH₄NO₃ M3 volume of no mol NO₂ at rtp using 1 mol = 24dm³ 18 000 000 dm³ of NO₂	3
(f)	fertiliser	1

76. 9701_w18_ms_21 Q: 2

(a)(i)	1 mark for each bullet, max 2 - triple bond - non-polar / no dipole - needs a lot of energy to break / strong	2
(a)(ii)	 6 e⁻ between atoms AND two electrons on each N atom	1
(b)(i)	(lightning) provides the (high) activation energy	1
(b)(ii)	M1 $\text{NO} + \frac{1}{2} \text{O}_2 \rightarrow \text{NO}_2$ M2 $2\text{NO}_2 + \text{H}_2\text{O} + \frac{1}{2} \text{O}_2 \rightarrow 2\text{HNO}_3$	2
(c)	M1 fertiliser / nitrates dissolve in (river / ground water) OR fertiliser / nitrates are washed / leached out / flows into (river/groundwater) M2 algal bloom / promote algal growth / explosion of plant growth AND sunlight is blocked out (preventing photosynthesis) / plants can no longer carry out photosynthesis (and die) AND bacteria break down or decay dead organisms / plants / algae M3 drop in oxygen (concentration)	3
(d)(i)	to increase / raise pH	1
(d)(ii)	M1 ammonia / NH_3 M2 displaces NH_3	2
(d)(iii)	M1 effervescence / fizzing / bubbling M2 solid disappears	2
(d)(iv)	$2\text{Ca}(\text{NO}_3)_2 \rightarrow 2\text{CaO} + 4\text{NO}_2 + \text{O}_2$	1

77. 9701_s17_ms_22 Q: 2

(a)	strong triple bond	1
	non-polar / no dipole	1
(b)(i)	Any 2 points covered correctly scores 2 marks Any 1 point covered correctly scores 1 mark - nitrogen (and oxygen) from the air / atmosphere (react): - high temperature (of internal combustion engine) / (engine) produces enough OR a lot of heat (energy) : (so) breaks (strong) bond(s) in nitrogen (and oxygen) :	2
(b)(ii)	reduction / decomposition of NO_x using a catalyst / catalytic convertor	1
	$2\text{NO}_2 + 4\text{CO} \rightarrow 4\text{CO}_2 + \text{N}_2$ OR $2\text{NO} + 2\text{CO} \rightarrow 2\text{CO}_2 + \text{N}_2$	1
(b)(iii)	(acts as a homogeneous) catalyst OR oxidising agent	1
	$\text{SO}_2 + \text{NO}_2 \rightarrow \text{SO}_3 + \text{NO}$	1
	$\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}_2$ OR $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$	1
(b)(iv)	$2\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_2 + \text{HNO}_3$ OR $4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{HNO}_3$	1
(c)	fertiliser / nitrates dissolve in (river water) OR fertiliser / nitrates are washed / leached out / flows into (river water)	1
	algal bloom / promote algal growth / explosion of plant growth AND EITHER sunlight is blocked out (preventing photosynthesis) / plants can no longer carry out photosynthesis (and die) OR bacteria break down or decay dead organisms / plants / algae	1
	drop in oxygen (concentration)	1
Total:		13

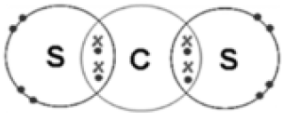
78. 9701_s16_ms_23 Q: 2

(a)	$\text{NH}_3 + \text{HNO}_3 \rightarrow \text{NH}_4\text{NO}_3$	[1]
(b) (i)	line from origin AND below left-hand end of original with peak to right of and lower than original crosses original once AND above right-hand end of original AND above energy axis	[1] [1]
(ii)	(curves show) more molecules with $E > E_a$ (at higher T) so greater frequency of successful (owtte) collisions / more successful (owtte) collisions per unit time	[1] [1]
(iii)	catalysed E_a shown to left of original on horizontal axis so more molecules with $E > E_a$ (in presence of catalyst)	[1] [1]
(iv)	production of ammonia is <u>exothermic</u> / (forward) reaction <u>exothermic</u> position of eqm would move to left / reverse / reduce yield (at higher T)	[1] [1]
(c)	$4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$ N changes from -3 to $+2$ (so oxidation) O changes from 0 to -2 (so reduction)	[1] [1] [1]
(d) (i)	$ \begin{array}{c} \text{H} \quad (+) \\ \cdot \\ \cdot \\ \text{H} \cdot \text{N} \cdot \text{H} \\ \cdot \\ \cdot \\ \text{H} \end{array} $	[1+1]
(ii)	shape = tetrahedral angle = 109° – 109.5°	[1] [1]
(e)	eutrophication / algal bloom / stimulates growth of algae (bacteria) use up oxygen when decomposing the plants / algae block light for plants so less oxygen produced aquatic life / fish die (due to lack of oxygen)	[1] [1] [1] [1]

79. 9701_w15_ms_21 Q: 2

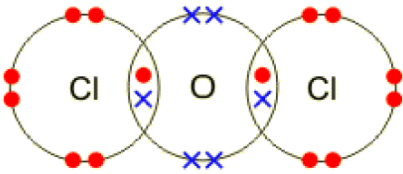
(a) (i)	The enthalpy change when one mole of a compound is formed from its element(s)	[1] [1]
(ii)	$\text{S(s)} + 1\frac{1}{2}\text{O}_2\text{(g)} \rightarrow \text{SO}_3\text{(l)}$	[1]
(b) (i)	$944 + (3 \times 436) = 2252$ $6 \times 390 = 2340$ $2252 - 2340 = -88 \text{ (kJ mol}^{-1}\text{)}$	[1] [1] [1]
(ii)	Fe catalyst 200 atm 400–500 ($^\circ\text{C}$)	[1] [1] [1]
(iii)	High T increases rate AND Low T improves yield owtte Chosen temp is a compromise High P favours / increases (both rate and) yield owtte pressure chosen limited by cost (of compression and 'thick walls')	[1] [1] [1] [1]
(c) (i)	$2\text{NH}_3 + \text{H}_3\text{PO}_4 \rightarrow (\text{NH}_4)_2\text{HPO}_4$	[1]
(ii)	NH_3 identified as base AND H_3PO_4 identified as acid base accepts protons AND acid donates protons	[1] [1]
(d) (i)	nitrates / fertilisers wash into rivers eutrophication / algal bloom / promote algal growth bacteria use up oxygen in decay process	[1] [1] [1]
(ii)	(oxides of nitrogen / NO_x / NOs) cause acid rain $2\text{NO}_2 + \text{H}_2\text{O} \rightarrow \text{HNO}_2 + \text{HNO}_3$ OR $4\text{NO}_2 + 2\text{H}_2\text{O} + \text{O}_2 \rightarrow 4\text{HNO}_3$ OR $\text{SO}_2 + \text{NO}_2 \rightarrow \text{SO}_3 + \text{NO}$ AND $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$	[1] [1]

80. 9701_w21_ms_21 Q: 1

Question	Answer	Marks
(a)(i)	easily vaporised / easily evaporates / turns to gas easily	1
(a)(ii)	 M1 bonding pairs M2 Correct number of remaining outer electrons	2
(a)(iii)	180°	1
(a)(iv)	M1 CS₂ has more electrons M2 So stronger induced dipole (forces) (between molecules)	2
(b)(i)	M1 (enthalpy/energy change when) 1 mole of a compound M2 burns/combusts/reacts in excess oxygen/O₂ OR completely burns/ completely combusts/completely reacts in oxygen/O₂	2
(b)(ii)	M1 (–394 +2 (–297) – (+89.7)) M2 = –1080 (kJ mol^{–1})	2
(c)(i)	weak [acid] partially dissociates/partially ionises (into H ⁺ ions/protons)	1
(c)(ii)	HS [–]	1

Question	Answer	Marks
(c)(iii)	M1 S (increases) oxidation number –2 → 0 so oxidation / or is oxidised M2 O (decreases) O.N. 0 → –2 so reduction / is reduced	2
(d)(i)	M1 moles of As₂S₃ = 0.198 / 246.1 / 8.05 × 10^{–4} M2 moles SO₂ (using moles of As₂S₃ as limiting factor) = 2.41(36) × 10^{–3} moles (6 / 2 × 8.05 × 10^{–4}) Volume SO₂ = 2.41(36) × 10^{–3} × 24 = 0.0579 dm³ M3 Moles O₂ used in reaction = 8.05 × 10^{–4} × 9 / 2 = 3.62 × 10^{–3} Volume O₂ used in reaction = 3.62 × 10^{–3} × 24 = 0.0869 dm³ M4 Final total volume gas = (0.1 – 0.0869) + 0.0579 = [0.0131 + 0.0579] = <u>0.071</u>(0) dm³ M4 ONLY award 4th mark if the final answer rounds to <u>0.071</u> Answer to minimum of 2 sig figs MAX 3 for using ecf from M1 to M2 to M3 and M4 Award all 4 marks if final answer rounds to 0.071	4
(d)(ii)	acid rain	
(d)(iii)	M1 SO₂(g) + 2NaOH(aq) → Na₂SO₃(aq) + H₂O(l) AND correct species and balancing M2 State symbols	2

81. 9701_w20_ms_21 Q: 2

(a)(i)	$P_4 + 5O_2 \rightarrow P_4O_{10}$	1			
(a)(ii)	any two from: - reacts vigorously - solid disappears / colourless solution forms - hydrolysis - exothermic - acid(ic) (solution) - steamy / misty fumes	2			
(a)(iii)	Simple and covalent OR molecular and covalent	1			
(b)(i)	M1: proton / H^+ donor M2: partially dissociates (in solution)	2			
(b)(ii)	$SO_2 + H_2O \rightarrow H_2SO_3$	1			
(b)(iii)	(homogeneous) catalyst	1			
(c)(i)	thermal decomposition	1			
(c)(ii)	M1: $\Delta H_f = -1434 - (-635 + -297)$ M2: $= -502 \text{ (kJ mol}^{-1}\text{)}$	2			
(d)(i)		1			
(d)(ii)	<table border="1" style="display: inline-table; vertical-align: middle;"> <tr> <td>0</td> <td>(+)4</td> <td>-1</td> </tr> </table>	0	(+)4	-1	1
0	(+)4	-1			
(d)(iii)	(at 1000 K and 100 kPa) M1: (yield) decreases M2: reaction is exothermic AND equilibrium moves left (at 500 K and 500 kPa) M3: (yield) increases M4: fewer moles (<u>of gas</u>) on right-hand side AND equilibrium moves right	4			
(e)(i)	M1: ionic M2: ions only able / free to move / free to conduct (when liquid / molten)	2			
(e)(ii)	M1: covalent M2: hydrolysed (by water)	2			

82. 9701_s19_ms_23 Q: 4

(a)	M1 sulfur impurities OR sulfur in fossil fuels M2 converted into SO ₂ by combustion / burning sulfur OR heat sulfur with oxygen (from the air)	2
(b)(i)	M1 1 mol SO ₂ → 1 mol H ₂ SO ₄ 64.1 g / tonne → 98.1 g / tonne M2 SO ₂ → 98.1 / 64.1 × 1590 = 2433.369735 tonnes	2
(b)(ii)	high (enough) temperature / (a lot of) heat (energy) is produced AND to break (strong) triple bond in N ₂ / break N≡N AND nitrogen (and oxygen) from the air / atmosphere react Award two marks for three correct points Award one mark for two correct points	2
(b)(iii)	lightning	1
(b)(iv)	M1 nitrogen dioxide increases the rate OR lowers the activation energy M2 (NO ₂) is regenerated by reaction of NO with O ₂ (in the air) OR NO (formed) reacts with O ₂ (in air) to (re)form NO ₂	2

83. 9701_w19_ms_22 Q: 1

(a)(i)		1
(a)(ii)	$\text{Si(g)} \rightarrow \text{Si}^+(\text{g}) + \text{e}^-$	1
(a)(iii)	M1: similar shielding AND increase in proton number / atomic number / nuclear charge M2: increased nuclear attraction	2
(a)(iv)	M1: 3 OR 13 M2: large(r) <i>increase</i> between third and fourth ionisation energies OR large(r) <i>increase</i> after third electron removed	2
(b)(i)	M1: $\frac{92.2 \times 28 + 6.6 \times 29 + 1.2 \times 30}{100} = 28.09$ M2: ($x =$) 6.6 OR $28.09 = 28.078 + x$ (where x = abundance of Si-29) M3: 7.8 – M2 calculated correctly to one decimal place (or more) (=) 1.2%	3
(b)(ii)	M1 giant (molecule) M2 strong covalent bonds (between atoms / particles) M3 no mobile charged particles / carriers	3
(c)(i)	$\text{C}_2\text{H}_5\text{SH} + 4\frac{1}{2}\text{O}_2 \rightarrow 2\text{CO}_2 + 3\text{H}_2\text{O} + \text{SO}_2$	1
(c)(ii)	M1: (causes) acid rain OR reacts/dissolves with (rain)water (vapour) to form (sulfuric / sulfurous) acid M2: one point from the following list. ☐ lowers pH / increases acidity of rivers / lakes / oceans / water supplies / seas / soil / ground water ☐ kills/harms / damages fish ☐ kills / harms / damages plants / damages coral / aquatic life / plants / crops / trees or deforestation ☐ leaches (toxic) aluminium (ions / salts) from soil (into rivers / lakes) ☐ leaches away soil nutrients / soil unfit for agriculture ☐ damages / weathers / erodes / destroys buildings / statues	2
(d)(i)	M1: no effect / none M2: equal mol(es) (of gas) on both sides (of equilibrium / equation) owtte	2
(d)(ii)	M1: (forward reaction is) endothermic M2: Any temperature higher than 300 K	2

84. 9701_w18_ms_21 Q: 1

(a)(i)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 (4s^0)$	1
(a)(ii)	-1	1
(b)	M1 attraction/hold M2 positive ions / cations AND delocalised electrons (may be seen in a labelled diagram)	2
(c)(i)	M1 <u>acid rain</u> M2 - destroys / damages / weathers / erodes / buildings / statues - kills/harms fish / coral / plants / crops / trees / deforestation - leaches salts / ions (aluminium) from soil (into rivers / lakes) - leaches away soil nutrients - breathing difficulties - lowers pH / increases acidity of soil / rivers / oceans / seas	2
(c)(ii)	balanced equation with $11O_2$ and $8SO_2$ M1: O_2 and SO_2 M2: 11 and 8	2
(c)(iii)	M1 is for process of calculating number of moles of Fe_2O_3 $33.18 \div 159.6 (= 0.2079 \text{ mol})$ M2 for correct use of stoichiometry and 120.0 with candidate's M1 M2 $(0.2079) \times 4 / 2 \times 120.0 = 49.89 \text{ (g)}$	2
(c)(iv)	$(0.37 / (0.37 + 49.89)) = 0.74$	1

85. 9701_w18_ms_22 Q: 2

(a)	<table><tr><td>Na</td><td>Mg</td><td>Al</td><td>Si</td><td>P</td></tr><tr><td>metallic</td><td>metallic</td><td>metallic</td><td>covalent</td><td>covalent</td></tr><tr><td>Na₂O</td><td>MgO</td><td>Al₂O₃</td><td>SiO₂</td><td>P₄O₁₀</td></tr><tr><td>NaCl</td><td>MgCl₂</td><td>AlCl₃</td><td>SiCl₄</td><td>PCl₅</td></tr></table> [1] for each correct row	Na	Mg	Al	Si	P	metallic	metallic	metallic	covalent	covalent	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀	NaCl	MgCl ₂	AlCl ₃	SiCl ₄	PCl ₅	3
Na	Mg	Al	Si	P																		
metallic	metallic	metallic	covalent	covalent																		
Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₄ O ₁₀																		
NaCl	MgCl ₂	AlCl ₃	SiCl ₄	PCl ₅																		
(b)(i)		1																				
(b)(ii)	M1 profile for exothermic reaction [1] M2 identification of ΔH and E_a [1]	2																				
(c)(i)	graph rises to maximum for Si, then falls	1																				
(c)(ii)	Max. 3 from: - increasing strength of metallic bond; Na < Mg < Al OR stronger attraction between delocalised electrons and (positive) ion so melting point of Na < Mg < Al - Si is giant covalent AND it has the highest melting point due to breaking / presence of strong (covalent) bonds OR Si requires the most energy because the covalent bonds in Si are stronger than metallic bonds (in Na / Mg / Al) - P and S have weak(er) intermolecular forces / induced dipoles / van der Waals forces (than covalent / metallic bonds) so have low(er) melting points - S₍₈₎ has stronger / more intermolecular forces / van der Waals forces / induced dipoles than P₍₄₎ so melting point of S₍₈₎ is higher	3																				
(d)	P ₄ O ₁₀ + 6H ₂ O → 4H ₃ PO ₄	1																				
(e)	M1 acid rain [1] M2 any of the following [1] - lowers pH / increases acidity of rivers / lakes / oceans / water supplies / seas / soil / ground water - kills / harms / damages fish / coral / aquatic life / plants / crops / trees or deforestation - leaches (toxic) aluminium (ions / salts) from soil (into rivers/lakes) - leaches away soil nutrients / soil unfit for agriculture - damages / weathers / erodes / destroys buildings / statues - causes breathing difficulties	2																				
(f)	M1 process of 'first ionisation energy' involves the loss/removal of an electron [1] M2 Mg and Al AND S and P (in either order) [1] M3 For Al 3p (orbital / sub-level / sub-shell) is higher in energy / further from the nucleus / more shielded (than Mg) [1] <i>ora</i> M4 For S the pair of electrons in the (3)p-orbital repel [1] <i>ora</i>	4																				

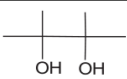
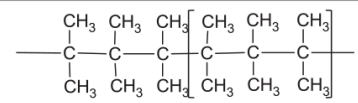
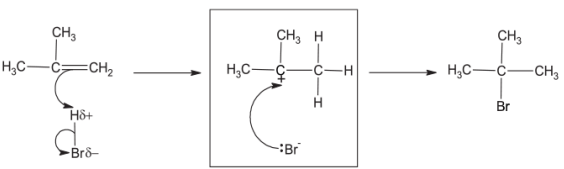
86. 9701_S15_ms_22 Q: 2

(a) (i)	$2\text{PbS} + 3\text{O}_2 \rightarrow 2\text{PbO} + 2\text{SO}_2$ reagents and formulae balancing	[1] [1]
(ii)	S (is oxidised) -2 to $(+)4$ O (is reduced) 0 to -2	[1] [1]
(b) (i)	T = $400 - 600^\circ\text{C}$ (chosen as a compromise because) High T increases rate ora High T decreases yield/moves eqm left/makes less SO_3 as forward reaction exothermic ora	[1] [1] [1]
(ii)	High pressure increases rate as collision frequency increases ora High pressure moves eqm right/favours forward reaction as more moles on left ora Uneconomic to use high pressures/high yield at low pressure	[1] [1] [1]
(c) (i)	Reaction (too) exothermic/acid spray produced	[1]
(ii)	$\text{SO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{S}_2\text{O}_7$ $\text{H}_2\text{S}_2\text{O}_7 + \text{H}_2\text{O} \rightarrow 2\text{H}_2\text{SO}_4$	[1] [1]
(d)	Preservative owtte antimicrobial/antioxidant/reducing agent	[1] [1]
(e) (i)	$12.35 \times 0.01 / 1000 = 1.235 \times 10^{-4}$	[1]
(ii)	$1.235 \times 10^{-4} \times 1000 / 50 = 2.47 \times 10^{-3}$	[1]
(iii)	$2.47 \times 10^{-3} \times 64.1 = 0.158327 \text{ g} = 158 \text{ (3 sf only)}$	[1]

87. 9701_w15_ms_22 Q: 3

(a) (i)	Na ₂ O or Na ₂ O ₂ ; MgO; P ₄ O ₁₀ or P ₄ O ₆ ; SO ₂	[1] [1]
(ii)	Na: Yellow / orange / gold flame / white solid / powder / smoke $4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$ or $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}_2$ S: Blue flame / (yellow) solid melts / turns red / amber / white fumes $\text{S} + \text{O}_2 \rightarrow \text{SO}_2$	[1] [1] [1] [1]
(b) (i)	acidic P and S amphoteric Al and basic Na and Mg	[1] [1]
(ii)	acidic: covalent (bonding) basic: ionic (bonding)	[1] [1]
(iii)	Al ₂ O ₃ + 6HCl → 2AlCl ₃ + 3H ₂ O OR Al ₂ O ₃ + 6H ⁺ → 2Al ³⁺ + 3H ₂ O Al ₂ O ₃ + 2NaOH + 7H ₂ O → 2NaAl(OH) ₄ (H ₂ O) ₂ OR Al ₂ O ₃ + 2NaOH + 3H ₂ O → 2NaAl(OH) ₄ OR Al ₂ O ₃ + 2NaOH → 2NaAlO ₂ + H ₂ O OR Al ₂ O ₃ + 2OH ⁻ + 7H ₂ O → 2[Al(OH) ₄ (H ₂ O) ₂] ⁻ OR Al ₂ O ₃ + 2OH ⁻ + 3H ₂ O → 2[Al(OH) ₄] ⁻ OR Al ₂ O ₃ + 2OH ⁻ → 2AlO ₂ ⁻ + H ₂ O	[1] [1]
(c)	sulfur forms SO ₂ / SO ₂ + / mixes H ₂ O → H ₂ SO ₃ or in words OR SO ₂ + / mixes H ₂ O (→ acid) / or in words OR SO ₂ + / mixes H ₂ O + (1/2O ₂) → H ₂ SO ₄ / or in words	[1] [1]

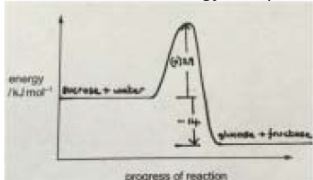
88. 9701_w16_ms_21 Q: 4

(a)(i)	4-methylhex-2-ene	1	1
(a)(ii)	(Molecules with the) same structural formula (and same molecular formula) with different arrangement of atoms/groups (in space)	1	1
(a)(iii)	4 double-bond / alkene (2) different groups on each double-bonded carbon (one) chiral carbon (centre) / (one) carbon atom has 4 different groups attached / is asymmetric / is chiral	1 1 1 1	4
(b)(i)	2,3-dimethylbut-2-ene	1	1
(b)(ii)		1	1
(b)(iii)	Propanone	1	1
(b)(iv)		1	1
(c)(i)	(2-)methylprop(-1-)ene	1	1
(c)(ii)		4	4
(c)(iii)	(tertiary carbocat)ion / (tertiary) intermediate is / C+ with least number of hydrogen atoms bonded to it is more stable (than primary) due to (positive) inductive effect of three/more methyl groups (cf one) / three / more electron releasing methyl groups three / more electron donating methyl groups reducing charge (density) on C+	1 1 1	3
Total:			18

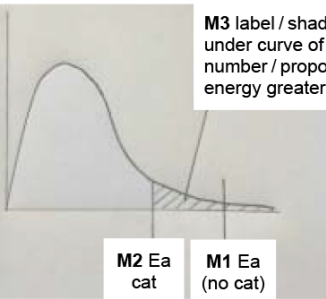
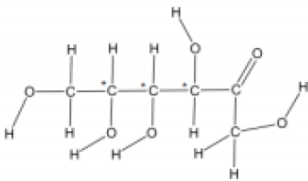
89. 9701_m20_ms_22 Q: 1

(a)(i)	$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$	1																
(a)(ii)	OH^- / hydroxide	1																
(b)	M1 (decreasing melting point down the group because) lower forces of attraction / weaker bonds (between cations and anions / oxide / O^{2-}) M2 larger cations and constant charge OR decreasing charge density of cation (down group)	2																
(c)	high(er) activation energy / heating overcomes activation energy	1																
(d)	$180(^{\circ})$	1																
(e)(i)	reacts with / behaves as both acid and base	1																
(e)(ii)	$\text{BeO} + 2\text{OH}^- + \text{H}_2\text{O} \rightarrow \text{Be(OH)}_4^{2-}$	1																
(f)(i)	M1 equal rates of forward and backward reactions M2 closed system OR macroscopic properties unchanging	2																
(f)(ii)	M1 <table><tr><td></td><td>Cl_2</td><td>O_2</td><td></td></tr><tr><td>initial</td><td>x</td><td>0</td><td>mol</td></tr><tr><td>equilibrium</td><td>$0.3x$</td><td>$0.35x$</td><td>mol</td></tr><tr><td>mol fraction</td><td>$\frac{6}{13}$</td><td>$\frac{7}{13}$</td><td></td></tr></table> M2 $K_p = \frac{100\,000 \times \frac{7}{13}}{(100\,000 \times \frac{6}{13})^2} = 2.53 \times 10^{-5}$ M3 Pa^{-1}		Cl_2	O_2		initial	x	0	mol	equilibrium	$0.3x$	$0.35x$	mol	mol fraction	$\frac{6}{13}$	$\frac{7}{13}$		3
	Cl_2	O_2																
initial	x	0	mol															
equilibrium	$0.3x$	$0.35x$	mol															
mol fraction	$\frac{6}{13}$	$\frac{7}{13}$																
(g)(i)	-1	1																
(g)(ii)	M1 (enthalpy / energy change) when one mole of a compound / substance is formed M2 from its elements in their standard states	2																
(g)(iii)	$-(-602 + -188) + (\Delta H_f[\text{MgO}_2] + -286) = -96$ $\Delta H_f[\text{MgO}_2] = -600 \text{ (kJ mol}^{-1}\text{)}$	2																
(g)(iv)	$-(-600) - (+602) = -2 \text{ (kJ mol}^{-1}\text{)}$	1																

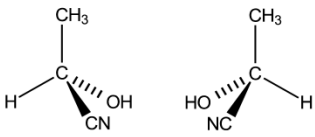
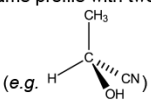
90. 9701_s20_ms_22 Q: 3

(a)	hydrolysis	1
(b)	M1 both have molecular formula - $C_6H_{12}O_6$ M2 idea that in glucose and fructose there are the same number and type of atoms present but the atoms are arranged in a different order ie one has a carbonyl group at the end of the chain/molecule and the other has a carbonyl group in the middle of the chain/molecule	2
(c)(i)	value for the activation energy for the reaction A (no enzyme) compared to reaction B (with enzyme) value / range of values that are more (+) 29 kJ mol^{-1}	1
(c)(ii)	value for the enthalpy change for reaction A (no enzyme) compared to reaction B (with enzyme) -14 kJ mol^{-1}	1
(c)(iii)	M1 show the energy of the reactants > products AND label ΔH using the predicted value given in (ii) M2 show activation energy 'hump' AND label using the value given in (i) 	2
(d)(i)	M1 (enthalpy change) when 1 mole of sucrose M2 burns/combusts/reacts in excess air/oxygen OR completely burns/combusts/reacts in air/oxygen	2
(d)(ii)	M1 for finding amount of energy released per gram of sucrose using $\Delta H / Q = mc\Delta T$ OR $\Delta H = -mc\Delta T$ $= (-)250 \times 4.18 \times (40.7 - 25) = (-)16406.5 \text{ J per gram OR } (-)16.4065 \text{ kJ / g}$ M2 for finding amount (mol) sucrose in 1g = $1/342 \text{ mol}$ M3 = $M1 / (M2 \times 1000)$ $\Delta H = -5610 \text{ kJ mol}^{-1}$ (3 sig figs) OR $-5611 \text{ kJ mol}^{-1}$ (4 sig figs)	3

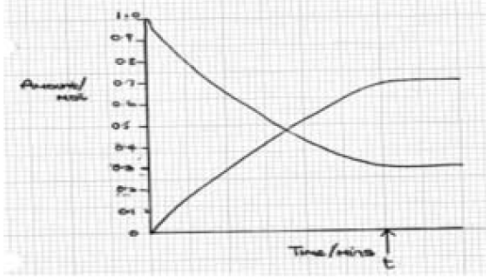
91. 9701_s20_ms_23 Q: 3

(a)(i)	hydrolysis	1
(a)(ii)		3
(b)(i)	an atom which is bonded to four different substituents / groups / atoms	1
(b)(ii)	ALL three chiral carbons need to be shown by * 	1
(b)(iii)	empirical formula of fructose CH ₂ O	1
(c)(i)	M1 (enthalpy change) when 1 mole of a substance M2 burns/combusts/reacts in excess air/oxygen OR completely burns/combusts/reacts in air/oxygen	2
(c)(ii)	$C_{12}H_{22}O_{11} + 12 O_2 \rightarrow 12CO_2 + 11H_2O$	1
(c)(iii)	M1 $\Delta H = -5643 - (-2805 + -2810)$ M2 $= -28 \text{ kJ mol}^{-1}$	2

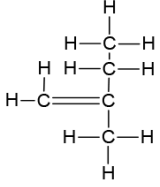
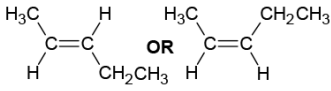
92. 9701_s19_ms_21 Q: 5

(a)	M1 a lone pair / electron pair donor	1
	M2 $(:)\text{CN}^- / ^-(:)\text{CN} / \text{cyanide ion}$	1
(b)(i)	optical	1
(b)(ii)	 M1 one 3-D structure of correct molecule shown. M2 a mirror image of the molecule drawn in M1 OR same profile with two groups swapped  M3 central chiral C shown as *	1
(c)	CH ₃ CH(OH)CO ₂ H OR HO ₂ CCH(OH)CH ₃	1

93. 9701_s19_ms_22 Q: 1

(a)(i)	C ₄ H ₁₀ / same molecular formula / OR same number of carbon (atoms) and hydrogen (atoms)	1
	different structural formula OR description of different structural formula which does not imply stereoisomerism	1
(a)(ii)	structural / chain	1
(b)	(forward reaction is) exothermic reaction	1
	the proportion of methylpropane / product decreases OR the proportion of butane / reactant increases	1
(c)(i)	t shown on graph which corresponds to start of the horizontal part of both curves. 	1
(c)(ii)	concentration of butane = 0.3 mol dm ⁻³ AND concentration of methylpropane = 0.7 mol dm ⁻³	1
(c)(iii)	[methylpropane] / [butane] OR [(CH ₃) ₂ CHCH ₃] / [CH ₃ (CH ₂) ₂ CH ₃]	1
(c)(iv)	M1 value for K_c $K_c = \frac{\text{value of methylpropane in (ii)}}{\text{value of butane in (ii)}} = 0.7 / 0.3 = 2.3$ (3)	1
	M2 units consistent with expression used in M1 no units / dimensionless / none	1

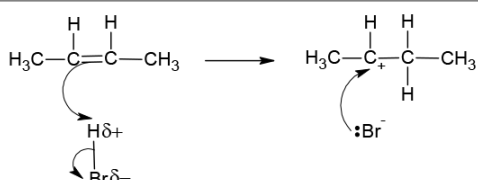
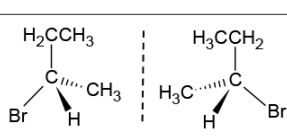
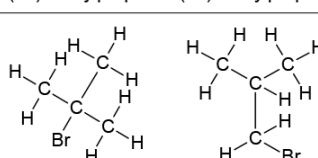
94. 9701_s18_ms_23 Q: 2

(a)(i)	(molecules / isomers with) the same molecular formula / same number of atoms of each element	1
	different structural formulae / different structures	1
(a)(ii)	(Molecules / isomers) with the same (molecular and) structural formula	1
	different arrangement of atoms in space / different spatial arrangement of atoms.	1
(b)(i)	two Hs on one of the C=C carbons / terminal C / C-1	1
	no chiral C / no C with 4 different groups / atoms / chains attached has a super(im)posable mirror image	1
(b)(ii)		1
	2-methylbut-1-ene	1
(b)(iii)	structure 	1
	trans-pent-2-ene or <i>E</i> - cis-pent-2-ene or <i>Z</i> -	1

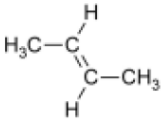
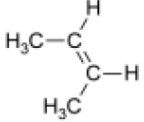
95. 9701_s17_ms_23 Q: 3

(a)(i)	(enthalpy / energy change) when one mole of a compound is formed	1
	from its elements in their standard states / standard conditions	1
(a)(ii)	$(\Delta H_f = \sum \Delta H_f \text{ products} - \sum \Delta H_f \text{ reactants})$ $-196 = 2\Delta H_f \text{ SO}_3 - (2 \times -296.8)$ $2\Delta H_f \text{ SO}_3 = -196 + (2 \times -296.8) = -789.6$	1
	$\Delta H_f \text{ SO}_3 = -394.8 \text{ (kJ mol}^{-1}\text{)}$	1
(b)(i)	Mark to right of original E_a	1
(b)(ii)	2 marks for any two points: - Benefit of using a catalyst in terms of increasing rate or economic benefit i.e. (less heat required) - Creates alternative pathway with lower E_a - More molecules with $E > E_a$	2
(b)(iii)	(rate) increases AND correct explanation in terms of 'more collisions'	1
	more successful collisions per unit time / higher chance of successful collisions per unit time / higher proportion of successful collisions per unit time	1
	(yield) increases and shifts equilibrium to the right / in the forward direction / towards SO_3 / towards the product / in exothermic direction	1
	to oppose the change or oppose the increase in pressure / fewer molecules on RHS so eqm moves to right (to oppose change)	1
(c)(i)	$\text{SO}_2 = 0.01 \text{ (mol)}$ AND $\text{SO}_3 = 0.99 \text{ (mol)}$	1
(c)(ii)	$n_{\text{TOT}} = 1.505$	1
	$p_{\text{O}_2} = 1.50 \times 10^5 \times (0.505 / 1.505) = 5.03 \times 10^4 \text{ (Pa)}$	1
(d)(i)	$(K_p =) \frac{p_{\text{SO}_3}^2}{p_{\text{O}_2} \times p_{\text{SO}_2}^2}$	1
(d)(ii)	0.1946737305	1
	Pa^{-1}	1
	Total:	17

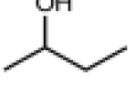
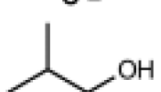
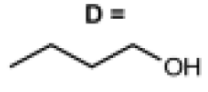
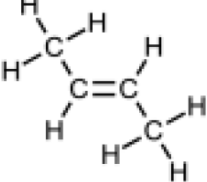
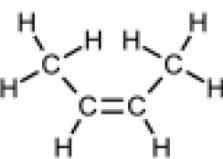
96. 9701_s17_ms_23 Q: 4

(a)	cracking	1
(b)	In any order $\text{CH}_2=\text{CHCH}_2\text{CH}_3$ / $\text{CH}_2\text{CHCH}_2\text{CH}_3$ / $\text{CH}_2\text{CHC}_2\text{H}_5$ AND $\text{CH}_3\text{CH}=\text{CHCH}_3$ / $\text{CH}_3\text{CHCHCH}_3$ AND $(\text{CH}_3)_2\text{C}=\text{CH}_2$ / $(\text{CH}_3)_2\text{CCH}_2$	1
(c)(i)	(different) molecules with the same (molecular and) structural formula	1
	(due to) different arrangement in space caused by $\text{C}=\text{C}$ / double bond	1
(c)(ii)	 arrow from the $\text{C}=\text{C}$ double bond drawn to the H dipole on $\text{H}-\text{Br}$ in correct orientation AND arrow from the $\text{H}-\text{Br}$ bond to the $\text{Br}^{\delta-}$ correct carbocation from the structure with $\text{C}=\text{C}$ drawn Br^- with lone pair, negative charge AND arrow from lone pair to the positively charged carbon atom of intermediate	1
(d)(i)	a (tetrahedral) atom with four different groups / atoms / substituents attached OR a carbon (atom) with four different groups / atoms / substituents attached	1
(d)(ii)	but-1-ene	1
(d)(iii)	 One 3D structure of 2-bromobutane which must have 2 bonds shown the same and two different, i.e. three bond types altogether, e.g. two solid lines, one wedge and one dash. If two bonds are drawn in the plane of the paper, i.e. single solid lines, they must not be at 180 degrees to each other. Second structure either mirror of first OR all bonds drawn the same with position of two groups swapped.	1
(d)(iv)	intermediate / (secondary carbo) cation from X is more stable ora OR charge density of C^+ (of the intermediate of X) is reduced	1
	(due to) electron-releasing character / (positive) inductive effect of alkyl groups / / due to electron releasing alkyl group	1
(e)(i)	(2-)methylpropene / (2-)methylprop-1-ene	1
(e)(ii)		2
Total:		17

97. 9701_s16_ms_21 Q: 4

(a)	$\text{CH}_2=\text{CHCH}_2\text{CH}_3 / \text{CH}_2\text{CHCH}_2\text{CH}_3$ AND $\text{CH}_3\text{CH}=\text{CHCH}_3 / \text{CH}_3\text{CHCHCH}_3$	[1]
(b)	$\text{CH}_2=\text{CHCH}_2\text{CH}_3 / \text{CH}_2\text{CHCH}_2\text{CH}_3$ AND $(\text{CH}_3)_2\text{C}=\text{CH}_2 / (\text{CH}_3)_2\text{CCH}_2$	[1]
(c)	 <i>trans</i>-but-2-ene (or <i>E</i>)  <i>cis</i>-but-2-ene (or <i>Z</i>)	 [1] [1]
(d)	B is $\text{CH}_2=\text{CHCH}_2\text{CH}_3$ OR $\text{CH}_3\text{CH}=\text{CHCH}_3$ OR $(\text{CH}_3)_2\text{C}=\text{CH}_2$ distinguished by addition of bromine brown/red/orange/yellow to colourless/decolourises with B (but not A)	 [1] [1] [1]

98. 9701_S15_ms_21 Q: 4

(a)	A =  $\longleftrightarrow$ chain isomerism B =  position isomerism $\nearrow$ $\nwarrow$ C =  $\longleftrightarrow$ chain isomerism D =  OR chain OR position isomerism $\nearrow$ $\nwarrow$ C =  $\longleftrightarrow$ chain isomerism D = 	[1] [1] [1] [1] [1] [1] [1]
(b) (i)	but-1-ene / 1-butene but-2-ene / 2-butene	[1] [1]
(ii)	but-2-ene AND two different groups on each carbon (of C=C) double bond means no free rotation	[1] [1]
(iii)	  and (either way round)	[1+1]

99. 9701_m21_ms_22 Q: 2

Question	Answer	Marks
2(a)	kills bacteria/microbes/micro-organisms	1
2(b)(i)	$\text{Cl(g)} - \text{e}^- \rightarrow \text{Cl}^+(\text{g})$	1

Question	Answer	Marks
(b)(ii)	M1: increasing proton number but similar shielding M2: greater attraction of nucleus (for outer / valence electrons)	2
(c)(i)	M1: (thermal stability) decreases (down group) M2: (H—X) bond energy / strength decreases	2
(c)(ii)	(+)6, (+)4, –2	1
(c)(iii)	halides are better / stronger / more able reducing agents / are more easily oxidised down group	1
(d)(i)	when a species is both oxidised and reduced	1
(d)(ii)	$\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$	1
(e)(i)	 M1: 2 × coordinate bonds in the right place M2: all other bonds	2
(e)(ii)	M1: • (AlCl₃ / solid) disappears • misty / steamy fumes • temperature increases M2: hydrolysis	2
(f)(i)	simple / molecular AND covalent	1

Question	Answer	Marks
(f)(ii)	M1: $11.54 \div 143.4 = 0.0805$ M2: so ratio Z:Cl is 1:4 / $n = 4$	2
(g)(i)	(free-)radical substitution	1
(g)(ii)	ultraviolet (UV) light / sunlight	1
(g)(iii)	$(1s^2) 2s^2 2p^6 3s^2 3p^5$	1
(g)(iv)	Cl· AND CH ₂ Cl ₂	1
(g)(v)	termination	1
(g)(vi)	CHCl ₃ OR (CH ₂ Cl) ₂	1

100. 9701_w19_ms_21 Q: 1

(a)(ii)	It oxidises chlorine from -1 to 0	1
(a)(ii)	effervescence / fizzing / bubbling OR green gas formed OR solid dissolves / disappears / soluble	1
(b)	M1: decreases (down the group) M2: increasing induced dipoles M3: greater number of electrons	3
(c)(i)	M1: $\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$ M2: chlorine is oxidised and reduced	2
(c)(ii)	NaClO_3 / sodium chlorate(V)	1
(d)	M1: chloric(I) acid / hypochlorous acid / HClO M2: kills bacteria / micro-organisms / microbes	2
(e)(i)	ultra-violet (light) / sunlight	1
(e)(ii)	$\text{C}_2\text{H}_6 + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{HCl}$	1

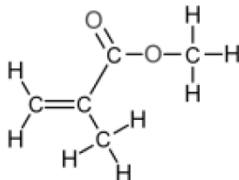
101. 9701_w19_ms_21 Q: 3

(a)(i)	cracking	1
(a)(ii)	enthalpy change of combustion / ΔH_c is high / large energy release (per mole / per unit mass) OR combust / burn easily	1
(a)(iii)	$\text{C}_4\text{H}_8 + 4\text{O}_2 \rightarrow 4\text{CO} + 4\text{H}_2\text{O}$	1
(a)(iv)	M1: infrared spectroscopy M2: Compare / measure (characteristic) wavelengths	2
(b)(i)	$\text{C}_4\text{H}_4\text{S(l)} + 6\text{O}_2\text{(g)} \rightarrow 4\text{CO}_2\text{(g)} + 2\text{H}_2\text{O(l)} + \text{SO}_2\text{(g)}$ - correct species - balancing - state symbols Award one mark for two correct bullet points, award two marks for all three correct.	2
(b)(ii)	M1 (enthalpy change when) 1 mol of a substance M2 EITHER burns / combusts / reacts in excess air / oxygen OR completely burns / combusts / reacts in air / oxygen	2
(b)(iii)	M1 $m = 200$ and $\Delta T = 37.5 - 18.5$ M2 $Q = mc\Delta T = 200 \times 4.18 \times (37.5 - 18.5) = 15\,884 \text{ (J)}$	2
(b)(iv)	M1 mol of thiophene used $= 0.63 / 84.1$ OR $7.49(1\,082\,045) \times 10^{-3}$ M2 calculation + 1000 AND negative sign $\Delta H_c = \frac{-(\text{iii})}{1000} \div n = \frac{-(\text{iii})}{21000} \div (0.63 / 84.1)$ $= -2120 \text{ (} -2120.39 \text{) (kJ mol}^{-1}\text{)}$	2

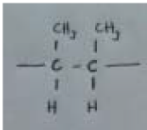
102. 9701_m18_ms_22 Q: 2

(a)(i)	simple molecular regular arrangement (of C ₆₀ molecules)	2
(a)(ii)	C ₆₀ has (weak) intermolecular / VdW / London / dispersion / id-id forces (and covalent bonds) diamond has covalent bonds (diamond's) bonds are stronger more energy required / lots of energy to break (covalent bonds in diamond)	4
(b)(i)	(a molecule / compound that is made up of) carbon and hydrogen (atoms) only	1
(b)(ii)	add bromine (water) / Br ₂ (aq) (brown to) colourless / decolourised	2
(c)(i)	addition	1
(c)(ii)	$(n_{C_{60}} = 0.144 / 720 =) 2 \times 10^{-4}$	1
(c)(iii)	$pV = nRT \quad \therefore \Delta n = (p_1 - p_2)V / RT$ $\Delta n = (1.00 \times 10^5 - 2.21 \times 10^4) \cdot 100 \times 10^{-6} / 8.31 \times 293$ $= 0.00320$	2
(c)(iv)	(C ₆₀ :H ₂) = $2.00 \times 10^{-4} : 0.00320$ or 1:16 C ₆₀ H ₃₂	2
(d)(i)	giant (molecular) (each Si has four) covalent (bonds)	2
(d)(ii)	1s ² 2s ² 2p ⁶ 3s ² 3p ⁶	1
(d)(iii)	Mg ₂ Si(s) + 4HCl(aq) → SiH ₄ (g) + 2MgCl ₂ (aq) species AND balancing state symbols	2
(d)(iv)	tetrahedral	1
(d)(v)	SiH ₄ + 2O ₂ → SiO ₂ + 2H ₂ O	1

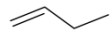
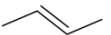
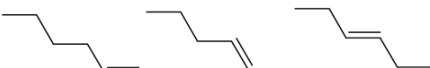
103. 9701_s18_ms_21 Q: 2

(a)	Different (hydrocarbon) molecules have different numbers of electrons	1
	so different strengths / numbers / amount of VdW / IMFs / id-id	1
(b)	Produces more useful / more valuable / higher demand substances / alkanes / alkenes	1
(c)(i)	C ₁₂ H ₂₆ → 2C ₂ H ₄ + C ₈ H ₁₈	1
(c)(ii)	addition polymerisation	1
(c)(iii)	two from save space in landfill avoid litter prevent eyesore non-biodegradable conserves non-renewable resources harmful incineration products harmful to wildlife	2
(c)(iv)		
	correct monomer	1
	fully displayed	1

104. 9701_s18_ms_22 Q: 3

(a)(i)	combustion	1
(a)(ii)	$C_8H_{18} + 12\frac{1}{2}O_2 \rightarrow 8CO_2 + 9H_2O$	
	correct species	1
	correct balancing	1
(b)(i)	cracking	1
(b)(ii)	-CH(CH ₃)CH(CH ₃)- OR 	
	even number of C's in correct backbone with 'end bonds' AND no C=C	1
	CH ₃ and H on each of two C drawn for 1 repeat unit only AND all the carbons must be tetravalent	1
(b)(iii)	addition	1
c(i)	catalytic converter / catalyst	1
c(ii)	$2CO + NO_2 \rightarrow 2CO_2 + \frac{1}{2}N_2$	1
c(iii)	(photochemical) smog / fog / haze OR global dimming	1
(d)(i)	any 2 from: lowers pH / increases acidity of rivers / lakes / oceans / seas / soil kills/harms fish OR harms / kills coral / plants / crops / trees leaches (toxic) aluminium (ions / salts) from soil (into rivers / lakes) leaches away soil nutrients damages / weathers / erodes buildings / statues	2
(d)(ii)	$NO_2 + SO_2 \rightarrow NO + SO_3$	1
	$SO_3 + H_2O \rightarrow H_2SO_4$	1
(d)(iii)	(it is) regenerated / not used up / undergoes temporary chemical change / recovered unchanged	1
	$NO + \frac{1}{2}O_2 \rightarrow NO_2$	1

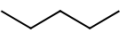
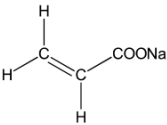
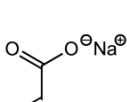
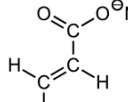
105. 9701_s17_ms_23 Q: 1

(a)	(molecules / isomers with) the same molecular formula / same number of atoms of each element	1
	different structural / displayed formulae / different arrangement of bonds	1
(b)(i)	4	1
(b)(ii)	6	1
(b)(iii)	molecular = C ₄ H ₈	1
	empirical = CH ₂	1
	using alternative supplied data molecular = C ₆ H ₁₂	
	empirical = CH ₂	
(b)(iv)		1
		1
	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	1
	calculation of n ($= pV / RT$) $n = \frac{100 \times 10^3 \times 25 \times 10^{-6}}{8.31 \times 310}$	1
	calculation of mass m ($= n \times M_r$) AND answer correct to 3sf $m = 9.705 \times 10^{-4} \times 56 = 0.0543 \text{ (g)}$	1
	Alternative answer for using C ₆ H ₁₂ : $m = 9.705 \times 10^{-4} \times 84 = 0.0815 \text{ (g)}$	
Total:		11

106. 9701_w15_ms_21 Q: 3

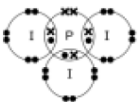
(a) (i)	structural isomers: (different molecules with) same molecular formula but different structural formulae	[1]
	chiral: has a carbon / C attached to 4 different groups / atoms / chains OR has no plane / line of symmetry / has non-superimposable mirror images	[1]
(ii)	CH ₃ CH ₂ CH(CH ₃)CH ₂ CH ₂ CH ₃ 3-methylhexane	[1] [1]
	CH ₃ CH(CH ₃)CH(CH ₃)CH ₂ CH ₃ / (CH ₃) ₂ CHCH(CH ₃)CH ₂ CH ₃ 2,3-dimethylpentane	[1] [1]
(b) (i)	C ₇ H ₁₆ + 11O ₂ → 7CO ₂ + 8H ₂ O	[1]
(ii)	C ₇ H ₁₆ + 4O ₂ → 7C + 8H ₂ O	[1]
(iii)	global dimming / PAN / smog / global warming	[1]
(c) (i)	(Free) Radical Substitution	[1]
(ii)	Cl ₂ → 2Cl• OR Cl ₂ → Cl• + Cl•	[1]
	C ₇ H ₁₆ + Cl• → •C ₇ H ₁₅ + HCl	[1]
	•C ₇ H ₁₅ + Cl ₂ → C ₇ H ₁₅ Cl + Cl•	[1]
	•C ₇ H ₁₅ + Cl• → C ₇ H ₁₅ Cl OR •C ₇ H ₁₅ + •C ₇ H ₁₅ → C ₁₄ H ₃₀	[1]
	Initiation; Propagation; Termination (used correctly)	[1]

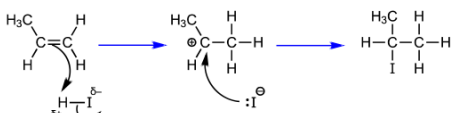
107. 9701_s21_ms_21 Q: 5

Question	Answer	Marks
(a)(i)	(compounds / molecules) containing only / entirely carbon and hydrogen (atoms)	1
(a)(ii)	crude oil	1
(b)(i)	(thermal) cracking	1
(b)(ii)	structure of <i>W</i>  OR CH ₃ (CH ₂) ₃ CH ₃ OR 	1
(c)(i)	CO ₂ H / carboxylic acid	1
(c)(ii)	M1 (add) Br ₂ (aq) / bromine water	1
	M2 (solution) turns (from brown / orange / red to) colourless / decolorises OR brown / orange / red fades	1
(d)	 OR CH ₂ CH(CO ₂ ⁻ Na ⁺) OR CH ₂ =CH(COO ⁻ Na ⁺)  OR  , etc.	1
(e)(i)	carbon dioxide / CO ₂	1
(e)(ii)	CO / hydrocarbons AND toxic / poisonous / harmful to health / (catalyses formation of) photochemical smog	1

108. 9701_w21_ms_22 Q: 1

Question	Answer	Marks
(a)(i)	M1 (HI / I / iodine / hydrogen iodide has a) greater number of electrons M2 greater induced dipoles (between molecules)	2
(a)(ii)	M1 bar at HF shows any boiling point above HI on graph M2 explanation of difference in boiling point of a sample of HF in terms of strength (sum of) hydrogen bonds (and induced dipoles in HF) are stronger than (sum of) induced dipoles (and permanent dipoles in HCl / HBr / HI)	2
(b)	(enthalpy / energy change) when one mole of a compound is formed from its elements in their standard states	2
(c)(i)	$K_p = \frac{p_{\text{HI}}^2}{p_{\text{H}_2} p_{\text{I}_2}}$	1
(c)(ii)	28.76 OR 28.8 OR 29	1
(c)(iii)	EITHER option 1 which assumes $\Delta H_{\text{reaction}}$ is (still) endothermic (using the value shown in (b)). M1 (K_p) decreases AND endothermic / ΔH_{f} = + / positive M2 reaction favours formation of reactants / hydrogen and iodine OR (product) yield / partial pressure of HI decreases / equilibrium shifts to the left OR option 2 which realises that $\Delta H_{\text{reaction}}$ is in fact exothermic (using bond energy data in Data Booklet) M1 (K_p) increases AND exothermic / ΔH_{f} = + / negative M2 reaction favours formation of products / hydrogen iodide yield increases / partial pressure of HI increases / equilibrium shifts to the right	2
(d)(i)	$4\text{HI} + \text{O}_2 \rightarrow 2\text{I}_2 + 2\text{H}_2\text{O}$	1

Question	Answer	Marks
(d)(ii)	M1 I / iodine (increases) oxidation number $-1 \rightarrow 0$ so oxidation / is oxidised OR HI / is oxidised as I (increases) oxidation number $-1 \rightarrow 0$ M2 O (decreases) oxidation number $0 \rightarrow -2$ so reduction / is reduced	2
(e)	M1 pressure increases M2 (pressure goes up as) number of moles/molecules increases in ratio 3 (gas) reactants to 5 (gas) products OR pressure is (directly) proportional to number of moles/molecules	2
(f)(i)	 M1 correct bonding pairs M2 correct number of remaining outer electrons on each atom	2
(f)(ii)	hydrolysis	1
(f)(iii)	proton donor / H^+ donor fully dissociates / fully ionises	2
(f)(iv)	H_2PO_3^-	1
(g)(i)	M1 2-iodopropane – formed from a (more) stable (secondary) (carbo)cation/intermediate M2 (because of) greater (positive) inductive effect / (+)I of two alkyl groups OR (because of positive) inductive effect / (+)I of more R / more methyl / more alkyl groups	2

Question	Answer	Marks
(g)(ii)	 M1 curly arrow from = of C=C to H AND curly arrow from bond of H—I to I M2 curly arrow from lone pair of I⁻ to C⁽⁺⁾ of their intermediate M3 correct carbocation AND product for 2-iodopropane	3

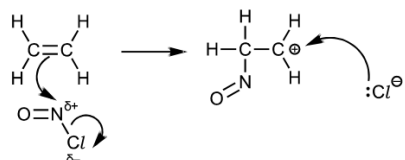
109. 9701_s20_ms_23 Q: 4

(a)	M1 (no reaction) not enough energy M2 bromine (free) radicals are not produced OR homolytic fission of bromine does not occur.	2
(b)(i)	free-radical substitution	1
(b)(ii)	$C_6H_{14} + (\cdot)Br \rightarrow (\cdot)C_6H_{13} + HBr$	1
(b)(iii)	$(\cdot)C_6H_{13} + Br_2 \rightarrow C_6H_{13}Br + (\cdot)Br$	1
(b)(iv)	$(\cdot)C_6H_{13} + (\cdot)Br \rightarrow C_6H_{13}Br$	1
(c)(i)	$CH_3(CH_2)_3CH=CH_2$	1
(c)(ii)	cold AND acidified AND dilute 2 marks for 3 correct conditions 1 mark for 2 correct conditions	2
(d)(i)	addition OR reduction	1
(d)(ii)	M1 only sigma / σ (bonds) in hexane / alkanes M2 B has sigma σ (bonds) and a / one pi / π (bond)	2

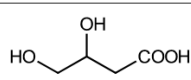
110. 9701_w20_ms_21 Q: 4

(a)(i)	M1: (Volatility) decreases (down the group) M2: more electrons so greater intermolecular forces / intermolecular attractions OR more electrons so greater VdW between molecules	2
(a)(ii)	(HI has the) lowest bond enthalpy	1
(a)(iii)	M1: HF has permanent dipole(-dipole forces) AND HI has ((only)) instantaneous dipole / induced dipole (forces) / permanent dipole(-dipole forces) M2: IMF's in HI are weaker (than IMF's in HF)	2
(a)(iv)	$3I_2 + 6NaOH \rightarrow 5NaI + NaIO_3 + 3H_2O$	1
(b)(i)	HI(g) / PI ₃ / P and I ₂	1
(b)(ii)	Electrophilic addition	1
(c)(i)	2(-)iodo(-)2(-)methylbutane	1
(c)(ii)	Nucleophilic substitution / S _N	1
(c)(iii)		1
(c)(iv)	(L has) two identical / two methyl groups attached to one end / one carbon of the C=C / double bond	1
(c)(v)	ethanoic acid / CH ₃ COOH	1
(c)(vi)	$CH_3COCH_3 + 3I_2 + 4OH^- \rightarrow (1)CH_3COO^- + 3H_2O + 3I^- + CHI_3$ M1: correctly balanced M2: CHI ₃ product	2
(c)(vii)	yellow ppt / yellow solid	1

111. 9701_m19_ms_22 Q: 1

(a)	strong triple bond / strong N≡N OR high activation energy / E_a OR non-polar	1				
(b)(i)	$3\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2$	1				
(b)(ii)	solid disappears	1				
(c)(i)	(it is used to make) fertilisers	1				
(c)(ii)	M1 CaO displaces NH_3 (from its salt / NH_4^+) M2 CaO is a stronger base / more basic (than NH_3)	2				
(d)(i)	<table border="1"><tr><td>NO</td><td>NO_2</td></tr><tr><td>(+)2 / (+)II</td><td>(+)4 / (+)IV</td></tr></table>	NO	NO_2	(+)2 / (+)II	(+)4 / (+)IV	1
NO	NO_2					
(+)2 / (+)II	(+)4 / (+)IV					
(d)(ii)	M1 $\frac{1}{2}\text{N}_2 + \text{O}_2 \rightarrow \text{NO}_2$ M2 $\text{Mg}(\text{NO}_3)_2 \rightarrow \text{MgO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$	2				
(d)(iii)	M1 $+82 (= E_{\text{O}=\text{O}} - 2E_{\text{N}=\text{O}}) = (+)496 - 2 \times E_{\text{N}=\text{O}}$ M2 $E_{\text{N}=\text{O}} = \frac{1}{2} \times (496 - 82) = \frac{1}{2} \times 414 = 207 \text{ (kJ mol}^{-1}\text{)}$	2				
(e)	 M1 curly arrow from C=C to $\text{N}^{\delta+}$ AND curly arrow from N—Cl to $\text{Cl}^{\delta-}$ M2 intermediate AND curly arrow from lone pair on Cl^- to $\text{C}^{\delta+}$	2				

112. 9701_m19_ms_22 Q: 4

(a)	3-chloroprop-1-ene	1
(b)(i)	ultra-violet (light) / sun(light)	1
(b)(ii)	$\text{CH}_2=\text{CHCH}_3 + \text{Cl}^\bullet \rightarrow \text{CH}_2=\text{CHCH}_2^\bullet + \text{HCl}$ OR $\text{C}_3\text{H}_6 + \text{Cl}^\bullet \rightarrow \text{C}_3\text{H}_5^\bullet + \text{HCl}$	1
(b)(iii)	free-radical (substitution) reactions are uncontrolled OR further chlorination / substitution occurs	1
(b)(iv)	SOCl_2 OR PCl_5 OR PCl_3 OR c(oncentrated) HCl	1
(c)(i)	cold, dilute acidified KMnO_4 / potassium manganate(VII)	1
(c)(ii)	M1 catalyst M2 ethanoic acid / $\text{CH}_3\text{CO}_2\text{H}$	2
(c)(iii)	nucleophilic substitution / $\text{S}_{\text{N}}2$	1
(c)(iv)	 M1 hydrolysed nitrile on straight-chain 4C backbone M2 3,4-diol	2
(d)	M1 major product formed from more stable intermediate / carbocation OR (intermediate has) 2° carbocation which is (more) stable M2 (positive) inductive effect / (+)I of alkyl groups (on the intermediate)	2

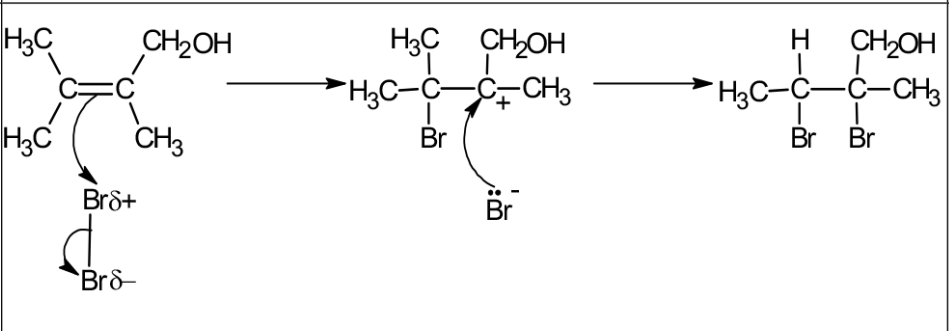
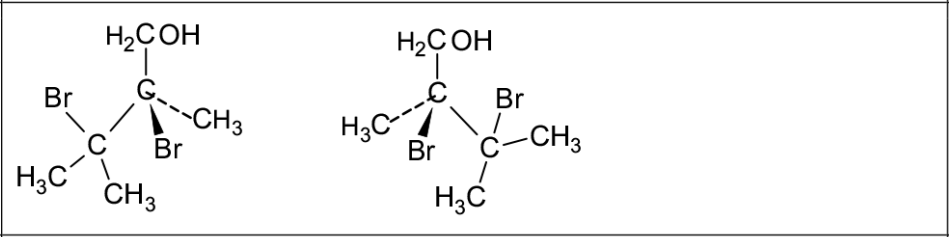
113. 9701_s19_ms_22 Q: 4

(a)	name of source crude oil / petroleum	1
	outline of separation of hydrocarbons (separation of molecules according to) different boiling points	1
(b)(i)	cracking	1
(b)(ii)	$2\text{C}_7\text{H}_{16} \rightarrow \text{C}_4\text{H}_{10} + \text{C}_6\text{H}_{14} + 2\text{C}_2\text{H}_4$	1
(c)	<i>method 1</i> <i>method 2</i>	
	M1 $1 / 28 (= 0.035714)$ $1 : 88 / 28 (= 3.14286)$	1
	M2 $2 \times \text{M1} (= 1 / 14 = 0.07143)$ $\text{M1} / 44 (= 0.071429)$	1
	M3 $\text{M2} \times 24 = 1.7 \text{ dm}^3$ $\text{M2} \times 24 = 1.7 \text{ dm}^3$	1
(d)(i)	unpaired electron(s)	1
(d)(ii)	homolytic (fission)	1
	one electron goes to each chlorine / atom	1
	OR pair of electrons is shared out (equally between the two atoms)	
(d)(iii)	propagation	1
(d)(iv)	$\text{CH}_4 + (\bullet)\text{Cl} \rightarrow (\bullet)\text{CH}_3 + \text{HCl}$ OR $\text{CH}_4 + (\bullet)\text{Cl} \rightarrow \text{HCl} + \text{CH}_3(\bullet)$	1
(d)(v)	M1 identify bond types in alkanes and alkenes bonds in alkanes are (all) sigma / σ AND alkenes have (C = C made of) sigma AND pi / σ AND π	1
	M2 electrons in π (of the C = C) are responsible for the reaction electrophiles are attracted to / attack to electrons in pi / π OR electrophiles react with pi / π	1

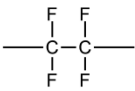
114. 9701_S15_ms_22 Q: 3

(a) (i)	Bond breaking = $\text{Cl-Cl} = 242$ $\text{C-H} = 410 = 652 \text{ kJ}$	[1]
	Bond forming = $\text{C-Cl} = 340$ $\text{H-Cl} = 431 = 771 \text{ kJ}$	[1]
	Enthalpy change = $652 - 771 = -119$	[1]
(ii)	UV / High T / sunlight	[1]
(iii)	Initiation $\text{Cl}_2 \rightarrow 2\text{Cl}\cdot$	[1]
	Propagation $\text{C}_2\text{H}_6 + \text{Cl}\cdot \rightarrow \cdot\text{C}_2\text{H}_5 + \text{HCl}$	[1]
	$\cdot\text{C}_2\text{H}_5 + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_5\text{Cl} + \text{Cl}\cdot$	[1]
	Termination $\cdot\text{C}_2\text{H}_5 + \cdot\text{C}_2\text{H}_5 \rightarrow \text{C}_4\text{H}_{10}$	[1]
	All three names correctly assigned	[1]
(b) (i)	ethene	[1]
(ii)	KOH / NaOH	[1]
	ethanolic AND heat / reflux	[1]
(iii)	H_2 AND Pt or Ni (catalyst)	[1]

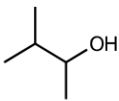
115. 9701_S15_ms_23 Q: 4

(a) (i)	$ \begin{array}{c} \text{H}_3\text{C} \quad \text{CH}_2\text{OH} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{HO} \quad \text{OH} \end{array} $	[1]
(ii)	$ \begin{array}{c} \text{CH}_3 \\ \\ \text{H}_3\text{C}-\text{C}=\text{O} \end{array} $	[1]
	$ \begin{array}{c} \text{COOH} \\ \\ \text{O}=\text{C} \\ \\ \text{CH}_3 \end{array} $	[1]
(b) (i)	 M1 = 2 curly arrows M2 = intermediate ion M3 = Br with -ve charge, lone pair and curly arrow to C+	[1] [1] [1]
(ii)	dipole is <u>induced</u> by proximity to C=C	[1]
(iii)	Optical	[1]
(iv)		[1+1]

116. 9701_w18_ms_21 Q: 3

(a)(i)	M1 gas / vapour (particles / molecules) in equilibrium (with liquid / solid) M2 greater proportion of gas (particles) than liquid (particles) (in comparison to a liquid of lower vapour pressure)	2
(a)(ii)	$-17.0 \text{ (kJ mol}^{-1}\text{)}$ ✓✓✓ M1 $\Delta H_r = x(-482.2) + y(-92.3) - v(-103.2) - w(-273.3)$ where x y v and w are integers ≥ 1 (ignore stoichiometry) M2 use of correct stoichiometry where $x = 1$ $y = 2$ $v = 1$ and $w = 2$	3
(a)(iii)	M1 in a different phase / state from reactants M2 a substance that speeds up a (chemical) reaction M3 catalyst is regenerated / not used up / undergoes temporary chemical change / recovered unchanged	3
(b)(i)	Human activity creates / additional / more/increase / thicker layer in greenhouse gas(es) / CHClF_2 OR Human activity has an impact on climate change / temperature at earth's surface / temperature of sea	1
(b)(ii)	M1 traps (more)heat M2 (in the atmosphere leading to) greater global warming or wtte	2
(b)(iii)	ozone depletion / thinning	1
(c)(i)	addition	1
(c)(ii)		1
(c)(iii)	molecule unreactive / inert	1
(c)(iv)	non-biodegradable creates toxic / harmful gases / HF / CO_2 / CO if burnt	2

117. 9701_m16_ms_22 Q: 4

(a) (i)	<u>C_4H_{10}</u>	[1]
(ii)	<u>C_4H_9</u>	[1]
(iii)		[1]
(b)	$\text{C}_8\text{H}_{18} + 12\frac{1}{2}\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$	[1]
(c)	sulfur dioxide would be produced on combustion (which contributes to) <u>acid rain</u>	[1] [1]
(d)	M1 = H has more /greater/ stronger van der Waals' /intermolecular forces than G / ora M2 = (because) H has more electrons (than G) M3 = J has hydrogen bonding (between molecules) M4 = strong(er) / great(er) forces require AND high / more energy to overcome	[1] [1] [1] [1]
(e)	NaOH(aq)	[1]

118. 9701_s16_ms_23 Q: 3

(a) (i)	vaporise/boil/turn to gas	[1]
(ii)	increasing molecular size/no of carbon atoms per molecule/length of carbon chain	[1]
(iii)	increasing b.pt/decreasing volatility increasing viscosity increasing density increasing depth of colour decreasing flammability/decreasing 'cleanliness' of flame owtte	[1] [1]
(b) (i)	$C_{12}H_{26} \rightarrow 2C_2H_4 + C_8H_{18}$	[1]
(ii)	ethene use = <u>making</u> polythene/plastic/polymers feature of ethene = double bond/unsaturated octane/alkane use = fuel/petrol feature of octane/alkane = flammability/releases energy when burned/combusted	[1] [1] [1] [1]
(c) (i)	(produced by) reaction of (atmospheric) oxygen and nitrogen due to high temperature/engine provides energy/combustion provides energy	[1] [1]
(ii)	$2NO + 2CO \rightarrow N_2 + 2CO_2$ / $NO + CO \rightarrow \frac{1}{2}N_2 + CO_2$	[1]
(iii)	$NO + \frac{1}{2}O_2 \rightarrow NO_2$ $NO_2 + SO_2 \rightarrow SO_3 + NO$ $SO_3 + H_2O \rightarrow H_2SO_4$ / $2H^+ + SO_4^{2-}$ / $H^+ + HSO_4^-$	[1] [1] [1]
(iv)	lowers pH of rivers/lakes/kills fish leaches (toxic) aluminium from soil (into rivers/lakes) leaches away soil nutrients damage to buildings/statues/trees/plants/crops ocean acidification/damage to coral	[1] [1] [1] [1] [1]

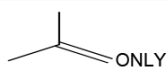
119. 9701_s21_ms_21 Q: 6

Question	Answer	Marks									
(a)	addition	1									
(b)	M1 catalyst = sulfuric acid / phosphoric(V) acid	1									
	M2 conditions of reaction = steam / heat (and pressure)	1									
(c)	<table border="1"> <thead> <tr> <th></th><th>σ</th><th>π</th></tr> </thead> <tbody> <tr> <td>C_3H_6</td><td>8</td><td>1</td></tr> <tr> <td>C_3H_8O</td><td>11</td><td>0</td></tr> </tbody> </table>		σ	π	C_3H_6	8	1	C_3H_8O	11	0	2
	σ	π									
C_3H_6	8	1									
C_3H_8O	11	0									
(d)(i)	M1 more stable = $CH_3C^+(H)(CH_3)$ 	1									
	M2 less stable = $CH_3CH_2C^+(H_2)$ / 	1									
	M3 greater (positive) inductive effect of two alkyl groups OR greater electron donation of two alkyl groups owtte	1									
(d)(ii)	propan-2-ol	1									
(e)(i)	elimination	1									
(e)(ii)	M1 NaOH / KOH	1									
	M2 ethanolic solution / ethanol / alcohol + heat	1									

120. 9701_w21_ms_21 Q: 2

Question	Answer	Marks				
(a)(i)	hydrogen / H ₂	1				
(a)(ii)	Ca(NO ₃) ₂ → CaO + 2NO ₂ + ½O ₂	1				
(a)(iii)	(thermal stability) increases	1				
(a)(iv)	CaCO ₃ + H ₂ O + CO ₂ → Ca(HCO ₃) ₂	1				
(b)	reduces acidity of soil	1				
(c)(i)	Mixing / overlap / combination of one / an s and one / a p orbital	1				
(c)(ii)	Sketch a diagram to show HOW two sp hybrid orbitals can form a SIGMA bond M1  M2 	2				
(d)(i)	M1 moles of NH₃ = 1.50 × 10⁶ × 10⁶ ÷ 17 = 8.82 × 10¹⁰ M2 mass of CaCN₂ = $\frac{\frac{1}{2} \times \text{M1} \times 80.1}{10^6} = 3.53 \times 10^6$	2				
(d)(ii)	<table><tr><td>CH₃CH₂CN</td><td>CH₃CH₂CO₂H</td></tr><tr><td>CH₃C(OH)(CN)CH₃</td><td></td></tr></table>	CH ₃ CH ₂ CN	CH ₃ CH ₂ CO ₂ H	CH ₃ C(OH)(CN)CH ₃		3
CH ₃ CH ₂ CN	CH ₃ CH ₂ CO ₂ H					
CH ₃ C(OH)(CN)CH ₃						

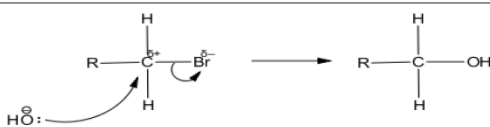
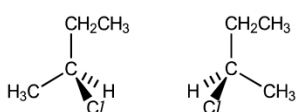
121. 9701_s20_ms_22 Q: 4

(a)(i)	Bromine / Br	1
(a)(ii)	$\text{Ag}^+(\text{aq}) + \text{X}(\text{aq}) \rightarrow \text{AgX}(\text{s})$ OR $\text{Ag}^+(\text{aq}) + \text{Br}(\text{aq}) \rightarrow \text{AgBr}(\text{s})$	1
(a)(iii)	M1 reagent Add (aqueous) ammonia M2 expected result EITHER (Dilute ammonia) – partial amount precipitate dissolves OR not much precipitate dissolves OR add concentrated ammonia – precipitate dissolves	2
(b)(i)	CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ Br	1
(b)(i)	M1 primary / 1° (carbo)cation formed is not very stable M2 EITHER (as) only one alkyl group exerting an inductive effect OR only one alkyl group so the charge is (more) localised on the C+	2
(c)(i)	elimination	1
(c)(ii)	$\text{C}_4\text{H}_9\text{Cl} + \text{NaOH} \rightarrow \text{C}_4\text{H}_8 + \text{NaCl} + \text{H}_2\text{O}$	1
(c)(iii)		1
(c)(iv)	M1 2-chloro(-2-)methylpropane M2 1-chloro(-2-)methylpropane ALLOW in any order	2

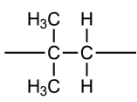
124. 9701_s18_ms_23 Q: 4

(a)(i)	2-bromobutane	1
(a)(ii)	ketone	1
(b)	$(\text{CH}_3)_3\text{CBr}$ $(\text{CH}_3)_2\text{CHCH}_2\text{Br}$ $\text{CH}_2\text{BrCH}_2\text{CH}_2\text{CH}_3$ 3 correct = 2 marks 2 correct = 1 mark	2
(c)(i)	S = substitution N = nucleophilic	1
(c)(ii)	M1 = dipole and curly arrow M2 = intermediate carbocation IGNORE CH_2CH_3 shown as C_2H_5 M3 = OH^- with lone pair and curly arrow from lone pair to the 'C'	3
(d)	$\text{C}_4\text{H}_9\text{Cl}$ slower (than $\text{C}_4\text{H}_9\text{Br}$) $\text{C}_4\text{H}_9\text{I}$ faster (than $\text{C}_4\text{H}_9\text{Br}$) $\text{C}-\text{Cl}$ bond stronger than $\text{C}-\text{Br}$ OR $\text{C}-\text{Cl}$ 340 $\text{C}-\text{Br}$ 280 $\text{C}-\text{I}$ bond weaker than $\text{C}-\text{Br}$ OR $\text{C}-\text{Br}$ 280 $\text{C}-\text{I}$ 240 1 mark for each point, max 3	3
(e)	ethanolic (instead of aqueous)	1
	hotter/higher temperature (heat under) reflux	1

125. 9701_w17_ms_21 Q: 3

(a)	<table><tr><th>reaction</th><th>reagent(s) and conditions</th><th>reaction type(s)</th></tr><tr><td>1</td><td>aqueous / aq / dilute NaOH / KOH OR water</td><td>substitution OR hydrolysis</td></tr><tr><td>2</td><td>alcoholic / ethanolic NaOH / KOH</td><td>elimination</td></tr><tr><td>3</td><td>NaCN / KCN in ethanol / alcohol</td><td>substitution</td></tr><tr><td>4</td><td>aqueous /dilute H₂SO₄ / H⁺(aq)</td><td>hydrolysis OR substitution OR addition-elimination</td></tr><tr><td>5</td><td>acidified / H⁺ (with) K₂Cr₂O₇ / Cr₂O₇²⁻ (and distil) NOT reflux</td><td>oxidation OR elimination</td></tr><tr><td>6</td><td>acidified / H⁺ K₂Cr₂O₇ / Cr₂O₇²⁻ Fehling's / Tollens' / Benedict's (reagent)</td><td>oxidation</td></tr></table>	reaction	reagent(s) and conditions	reaction type(s)	1	aqueous / aq / dilute NaOH / KOH OR water	substitution OR hydrolysis	2	alcoholic / ethanolic NaOH / KOH	elimination	3	NaCN / KCN in ethanol / alcohol	substitution	4	aqueous /dilute H ₂ SO ₄ / H ⁺ (aq)	hydrolysis OR substitution OR addition-elimination	5	acidified / H ⁺ (with) K ₂ Cr ₂ O ₇ / Cr ₂ O ₇ ²⁻ (and distil) NOT reflux	oxidation OR elimination	6	acidified / H ⁺ K ₂ Cr ₂ O ₇ / Cr ₂ O ₇ ²⁻ Fehling's / Tollens' / Benedict's (reagent)	oxidation	6
reaction	reagent(s) and conditions	reaction type(s)																					
1	aqueous / aq / dilute NaOH / KOH OR water	substitution OR hydrolysis																					
2	alcoholic / ethanolic NaOH / KOH	elimination																					
3	NaCN / KCN in ethanol / alcohol	substitution																					
4	aqueous /dilute H ₂ SO ₄ / H ⁺ (aq)	hydrolysis OR substitution OR addition-elimination																					
5	acidified / H ⁺ (with) K ₂ Cr ₂ O ₇ / Cr ₂ O ₇ ²⁻ (and distil) NOT reflux	oxidation OR elimination																					
6	acidified / H ⁺ K ₂ Cr ₂ O ₇ / Cr ₂ O ₇ ²⁻ Fehling's / Tollens' / Benedict's (reagent)	oxidation																					
(b)	 M1 lone pair on O of ⁻OH AND curly arrow from lone pair to C(—Br) M2 correct dipole on C^{δ+}—Br^{δ-} AND curly arrow from bond to Br	2																					
(c)(i)	(different molecules) with same molecular formula / same numbers of atoms of (each type) of element	1																					
	different structural formulae / displayed formulae	1																					
	chain / skeletal	2																					
	functional group																						
	position(al) / regioisomerism																						
	two types correct = 1 mark, all three correct = 2 marks																						
(c)(ii)	S _N / nucleophilic substitution	1																					
	((CH ₃) ₃ CBr / tertiary halogenoalkane) forms a stable (carbo)cation / stable intermediate (as charge density on cation is reduced) OR (in) 1-bromobutane / primary halogenoalkane there is no (stable) (carbo)cation / intermediate formed	1																					
	(because) there are (3 /more) alkyl / methyl groups AND (+) I / (greater) inductive effect OR (because) there is only one / fewer alkyl / methyl group(s) (compared to reaction with 2-bromo-2-methyl propane / tertiary halogenoalkane) AND limited (+) I / (less) inductive effect	1																					
(d)(i)	(different molecules) with the same (molecular and) structural formula /	1																					
	with different arrangements of <u>atoms</u> in space / spatial arrangement of <u>atoms</u>	1																					
(d)(ii)	mirror images are super(im)posable / no chiral carbon / no chiral centre / it is achiral	1																					
	(one) C of double bond has identical groups / H (atoms) (attached) OR (one) end of double bond has identical groups / 2 H (atoms) (attached)	1																					
(d)(iii)	X = 2-chlorobutane	1																					
	Y = 1-chlorobutane	1																					
(d)(iv)	optical (isomerism)	1																					
(d)(v)	one acceptable 3D structure of 2-chlorobutane	1																					
	the 2nd optical isomer EITHER drawn as a mirror image of the first OR the same bond pattern is shown but two of the groups swap positions.	1																					
																							

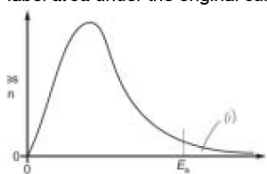
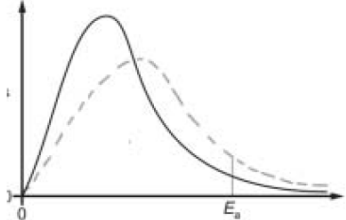
126. 9701_w17_ms_22 Q: 4

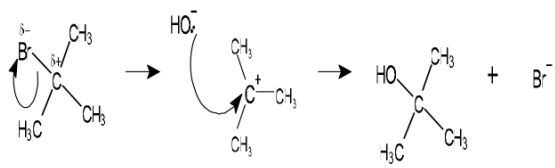
(a)	1	<u>concentrated</u> H_2SO_4 / H_3PO_4 AND NaBr OR (red) P / Br_2 OR HBr	substitution	5
	2	aqueous / dilute NaOH / KOH	hydrolysis OR substitution	
	3	<u>concentrated</u> H_2SO_4 / H_3PO_4 OR Al_2O_3 / P_4O_{10} / pumice / porous pot / SiO_2	dehydration	
	4	(ethanolic) HBr	addition	
	4 marks for column 1 (one per row) 1 mark for col 2			
(b)	 M1 correct dipole on $\delta^+\text{C}-\text{Br}^{\delta-}$ AND curly arrow from C—Br bond to Br M2 correct intermediate with + charge M3 curly arrow from lone pair on ^-OH to C^+ of carbocation			3
(c)(i)	(different molecules) same molecular formula / same numbers of atoms of each (type of) element			1
	different structural formulae / displayed formulae			1
	chain / skeletal functional group position(al) / regioisomerism two types correct = 1 mark, all three correct = 2 marks			2
(c)(ii)	S_N / nucleophilic substitution			1
	no (stable) (carbo)cation / intermediate is formed			1
	only one alkyl group / fewer alkyl / methyl groups (compared to reaction 2) AND limited (+)I / inductive effect / less electron donating (effect)			1
(d)(i)	mirror images are super(im)posable OR not chiral / no chirality / no chiral/asymmetric carbon/centre / achiral			1
	one or both C/end of double bond has identical groups / 2 methyl groups / 2 H (atoms)			1
(d)(ii)	addition			1
	 marking points: - correct number of tetravalent carbon atoms in backbone, with extension bonds - correct groups on backbone carbon atoms and only one repeat unit			2
(d)(iii)	not/non- biodegradable / harmful combustion products			1
(e)	2-bromo-2-methylpropane			1
	1-bromo-2-methylpropane			1

127. 9701_w16_ms_22 Q: 4

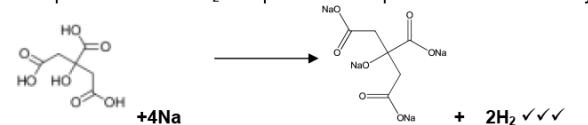
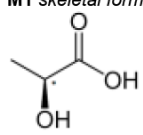
(a)(i)	2-bromobutane	1
(a)(ii)	e.g. of mirror images e.g. of swapped groups	1+1
(a)(iii)	$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$ $(\text{CH}_3)_2\text{CHCH}_2\text{Br}$ $(\text{CH}_3)_3\text{CBr}$	1 1 1
(b)(i)	3-bromo-3-ethylpentane	1
(b)(ii)	M1 = dipole and curly arrow from bond to (or just beyond) Br M2 = correct carbocation M3 = OH^- with curly arrow from lone pair <u>on O</u> to C(+)	1 1 1
(b)(iii)	$\text{S}_{\text{N}}1$ / nucleophilic substitution	1
(c)(i)	Sodium / potassium hydroxide	1
	Ethanol / alcohol AND heat	1
(c)(ii)	elimination	1
(c)(iii)		1 1 1
Total:		17

128. 9701_s21_ms_22 Q: 3

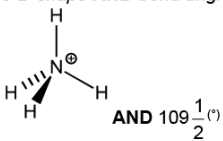
Question	Answer	Mark
(a)	change in amount of substance with time	1
(b)(i)	label area under the original curve to the right of E_a . 	1
(b)(ii)	M1 curve starts at the origin but peak lies to the right of original. M2 peak at higher temperature is lower than the original AND graph crosses the original once only – beyond the peak of original 	1
(b)(iii)	no change / none	1

Question	Answer	Mark
(c)(i)	 M1 correct dipole on haloalkane AND arrow from bond to Br or just beyond M2 correct intermediate M3 arrow from lone pair on O of OH^- / ^-OH to central C of their intermediate shown in M2 OR arrow from lone pair on O of OH^- / ^-OH to central C of 2-bromo 2-methylpropane if $\text{S}_{\text{N}}2$ mechanism shown	1
(c)(ii)	nucleophilic substitution	1
(d)	M1 more time (because the rate is lower) M2 C-Cl (bond) is stronger (than C-Br)	1

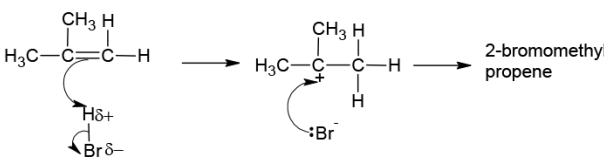
129. 9701_s21_ms_23 Q: 5

Question	Answer	Marks
(a)	M1 all 3 COOH form COONa / CO ₂ Na / COO ⁻ Na ⁺	1
	M2 the OH group forms CONa / CO ⁻ Na ⁺	1
	M3 equation describes H ₂ as a product and equation balanced correctly  OR $\text{C}(\text{CH}_2\text{COOH})_2(\text{COOH})(\text{OH}) + 4\text{Na} \rightarrow \text{C}(\text{CH}_2\text{COONa})_2(\text{COONa})(\text{ONa}) + 2\text{H}_2 \checkmark\checkmark\checkmark$	1
(b)(i)	M1 skeletal formula of 2-hydroxypropanoic acid / similar chiral isomer that meet the criteria in table 	1
	M2 chiral carbon marked with *	1
(b)(ii)	M1 citric acid has a tertiary alcohol group so is not oxidised	1
	M2 X has a secondary alcohol group which is oxidised (to a ketone)	1
(c)	M1 chiral centre / non superimposable mirror image / has a C attached to 4 different groups	1
	M2 C=C where each C is attached to (two) different groups	1
(d)	(molecules / isomers with) the same molecular formula / same number of atoms of each element AND different structural formulae / different structures	1

130. 9701_w19_ms_22 Q: 3

(a)(i)	green gas fades OR white solid / white powder / white smoke / white fumes	1
(a)(ii)	hydrolysis	1
(a)(iii)	☐ P goes from 0 to (+)5 / (+)V ☐ P is oxidised ☐ N goes from (+)5 / (+)V to (+)4 / (+)IV ☐ N is reduced Award one mark for two correct bullet points, award two marks for all four correct.	2
(b)(i)	accepts a proton / H^+ OR donates a (lone) pair of e^-	1
(b)(ii)	3-D shape AND bond angle  AND $109\frac{1}{2}^{\circ}$	1
(b)(iii)	fertilisers	1
(c)(i)	$C_2H_5OH + PCl_5 \rightarrow C_2H_5Cl + POCl_3 + HCl$	1
(c)(ii)	substitution	1
(c)(iii)	EITHER M1: HI / I^- is a strong(er) reducing agent (than HCl / Cl^-) M2: HI / I^- is oxidised (to iodine but the chloride is not) OR M1: H_2SO_4 is a (strong enough) oxidising agent (to react with HI / I^- here) M2: HI / I^- forms iodine OR M1: phosphoric acid is a weak / not an oxidising agent M2: (so) does not react with iodide (where M2 is dependent on M1 here)	2
(c)(iv)	M1: C_2H_5I reacts fastest AND C_2H_5Cl reacts slowest OR $C_2H_5Cl < C_2H_5Br < C_2H_5I$ M2: $C-I$ bond is the weak(est) AND $C-Cl$ bond strong(est)	2

131. 9701_s18_ms_21 Q: 4

(a)(i)	Iodoform / triiodomethane	1
(a)(ii)	butan-2-ol	1
(b)	CH ₃ CH ₂ CH ₂ CH ₂ OH (CH ₃) ₃ COH (CH ₃) ₂ CHCH ₂ OH	2
(c)(i)	oxidation / redox	1
(c)(ii)	acidified / H ⁺ AND potassium / sodium dichromate(VI) or formulae	1
(c)(iii)	<i>In any order:</i>	
	but-1-ene	1
	but-2-ene	1
	cis / Z- AND trans / E-	1
(d)(i)		
	curly arrow from C=C to H	1
	correct dipole on HBr and curly arrow from bond of HBr to Br	1
	tertiary intermediate cation	1
	Br ⁻ with curly arrow from lone pair	1
(d)(ii)	(carbo)cation / tertiary ion / tertiary intermediate (more) stable (than primary)	1
	due to electron-releasing / (positive) inductive effect of more alkyl / methyl groups	1

132. 9701_w15_ms_21 Q: 4

(a) (i)	CH ₃ CH ₂ OH + HCl → CH ₃ CH ₂ Cl + H ₂ O or CH ₃ CH ₂ OH + PCl ₅ → CH ₃ CH ₂ Cl + HCl + POCl ₃ or CH ₃ CH ₂ OH + SOCl ₂ → CH ₃ CH ₂ Cl + HCl + SO ₂	[1+1]
(ii)	NaOH/KOH warm/heat/reflux AND aqueous	[1] [1]
(b) (i)	CH ₂ =CH ₂ /ethene/C ₂ H ₄ /CH ₂ CH ₂	[1]
(ii)	White ppt/solid/suspension	[1]
(iii)	Ag ⁺ (aq) + Cl ⁻ (aq) → AgCl(s)	[1]
(c) (i)	CH ₃ CHO/ethanal	[1]
(ii)	CH ₃ CH ₂ OH higher bpt than CH ₃ CHO ora due to hydrogen bonding in ethanol/stronger IMFs prevents further oxidation owtte	[1] [1] [1]

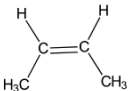
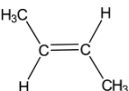
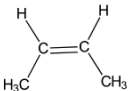
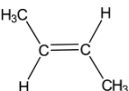
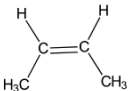
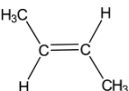
133. 9701_s21_ms_23 Q: 4

Question	Answer			Marks
(a)(i)	1,3-dichloropropan(-2-)one			1
(a)(ii)	carbonyl / ketone			1
(a)(iii)	NaBH ₄ OR LiAlH ₄			1
(b)	reagent	observation with Q	observation with R	4
	2,4-DNPH	M1 red / orange / yellow AND precipitate / solid / crystals	M2 red / orange / yellow AND precipitate / solid / crystals	
	Na ₂ CO ₃ (aq)	M3 no visible change	M4 fizz / effervescence	
(c)	step	reagent and conditions	type of rxn	5
	1	M1 HCN and (trace) KCN / NaCN	M3 Addition	
	2	dilute sulfuric acid	Hydrolysis	
	3	M2 KCN/NaCN in ethanol / alcohol	M4 Substitution	
	4	dilute sulfuric acid	Hydrolysis	
	M5 type of reaction for step 2 AND step 4			

134. 9701_m21_ms_22 Q: 4

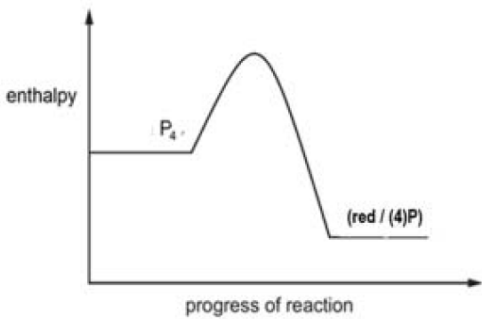
Question	Answer	Marks
(a)	M1: $x = 108-110^\circ$ M2: $y = 118-122^\circ$	2
(b)	M1: red / orange / yellow ppt / solid M2: silver mirror OR silver / grey / black / brown ppt / solid	2
(c)(i)	oxidising agent	1
(c)(ii)	M1: (excess dichromate and) heat under reflux M2: to allow full oxidation (of alcohol and aldehyde groups)	2
(d)(i)	$\text{CH}_2\text{OHCHO} + 2[\text{H}] \rightarrow (\text{CH}_2\text{OH})_2$	1
(d)(ii)	NaBH ₄ / LiAlH ₄	1
(d)(iii)	ethene	1

135. 9701_s21_ms_22 Q: 4

Question	Answer	Mark															
(a)(i)	<table border="1"> <thead> <tr> <th></th><th>structural formula</th><th>name</th></tr> </thead> <tbody> <tr> <td>A</td><td>$\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$</td><td>but-1-ene OR 1-butene</td></tr> <tr> <td>B</td><td>  </td><td>cis / Z but-2-ene OR cis / Z 2-butene</td></tr> <tr> <td>C</td><td>  </td><td>trans / E but-2-ene OR trans / E 2-butene</td></tr> <tr> <td>D</td><td>$\text{CH}_2=\text{C}(\text{CH}_3)_2$</td><td>(2) methyl prop(-1-)ene</td></tr> </tbody> </table> M1 correct identification of but-1-ene (for A) M2 correct identification of but-2-ene for B and C M3 identification of cis / trans (Z / E) for B and C (in correct order) M4 correct name of D		structural formula	name	A	$\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$	but-1-ene OR 1-butene	B		cis / Z but-2-ene OR cis / Z 2-butene	C		trans / E but-2-ene OR trans / E 2-butene	D	$\text{CH}_2=\text{C}(\text{CH}_3)_2$	(2) methyl prop(-1-)ene	4
	structural formula	name															
A	$\text{CH}_3\text{CH}_2\text{CH}=\text{CH}_2$	but-1-ene OR 1-butene															
B		cis / Z but-2-ene OR cis / Z 2-butene															
C		trans / E but-2-ene OR trans / E 2-butene															
D	$\text{CH}_2=\text{C}(\text{CH}_3)_2$	(2) methyl prop(-1-)ene															
(a)(ii)	(molecules with the) same structural formula (and same molecular formula) with different arrangement of atoms / groups in space	1															
(b)(i)	A	1															

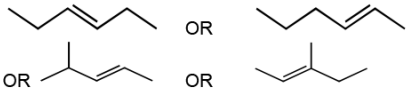
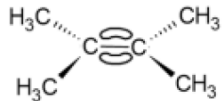
Question	Answer	Mark								
(b)(ii)	 M1 skeletal formula only M2 explanation in terms of increased / greater stability of intermediate / carbocation intermediate / (secondary) carbocation / $\text{CH}_3\text{C}^+(\text{H})(\text{CH}_2\text{CH}_3)$ is (more) stable M3 reason for increased stability of intermediate in terms of greater number of alkyl groups showing largest inductive (electron releasing) effect greater (positive) inductive effect due to two alkyl groups OR greater electron donation of two alkyl groups	1								
(c)	dehydrating agent / cause dehydration	1								
(d)(i)	oxidation	1								
(d)(ii)	<table><tr><th>functional group</th><th>present in Z</th></tr><tr><td>aldehyde</td><td>✓</td></tr><tr><td>ketone</td><td></td></tr><tr><td>carboxylic acid</td><td></td></tr></table>	functional group	present in Z	aldehyde	✓	ketone		carboxylic acid		1
functional group	present in Z									
aldehyde	✓									
ketone										
carboxylic acid										

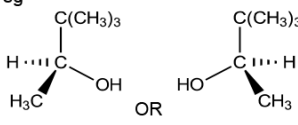
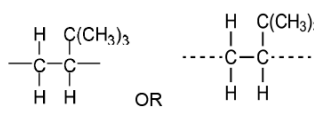
136. 9701_w21_ms_21 Q: 3

Question	Answer	Marks
(a)(i)	M1 simple molecular M2 giant molecular M3 weak IMFs (overcome) in P_4 AND strong (covalent) bonds (broken) in P	3
(a)(ii)		1
(b)(i)	(+5)/V	1
(b)(ii)	$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$	2
(c)(i)	$C_{18}H_{15}P$	1
(c)(ii)	stage 1 = reduction stage 2 = substitution	2

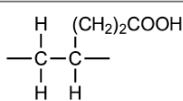
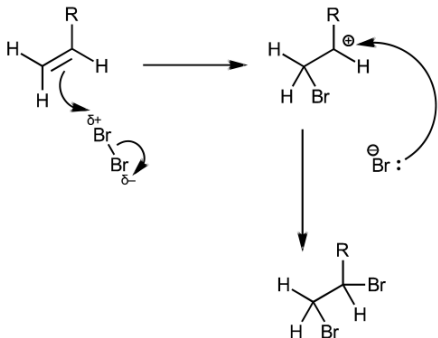
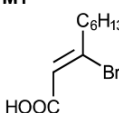
Question	Answer	Marks
(c)(iii)	G = $C_2H_5CH_2OH$ H = $C_2H_5CH=CHC_2H_5$	2
(d)	$CH_3CH_2CO_2H$ CH_3COCH_3	2

137. 9701_w21_ms_22 Q: 3

Question	Answer	Marks
(a)	(2,3)-dimethylbut-2-ene	1
(b)		1
(c)(i)		1
(c)(ii)	sp ²	1
(d)(i)	cold dilute acidified potassium manganate(VII)	1
(d)(ii)	M1 (2,4-DNPH will produce a) red / orange / yellow precipitate M2 V has a carbonyl group	2
(d)(iii)	M1 C—O in range 1040–1300 (cm ⁻¹) M2 C=O in range 1670–1740 (cm ⁻¹)	2
(e)(i)	yellow precipitate	1
(e)(ii)	Iodine / I ₂	1
(e)(iii)	C ₆ H ₁₂ O + 2[H] → C ₆ H ₁₄ O	1

Question	Answer	Marks
(e)(iv)	Draw two optical isomers of X. eg  M1 One correct 3-dimensional representation of X M2 3-d structure which represents the enantiomer of their X	1 1
(e)(v)	heat AND concentrated H ₂ SO ₄ / concentrated H ₃ PO ₄ / concentrated sulfuric [(VI)] acid / concentrated phosphoric[(V)] acid	1
(e)(vi)		1
(e)(vii)	high activation energy	1

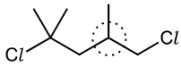
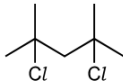
138. 9701_m20_ms_22 Q: 3

(a)(i)	M1 acidified / H^+ $\text{Cr}_2\text{O}_7^{2-}$ / (potassium / sodium) dichromate OR manganate(VII) / MnO_4^- / KMnO_4 M2 (heat under) reflux	2
(a)(ii)	nucleophilic addition	1
(a)(iii)	yellow / orange / red ppt / solid	1
(a)(iv)	it does not have four different (groups of) atoms attached to (central) carbon OR it does not have a chiral carbon / centre OR it has two identical / COOH groups attached to (central) carbon OR mirror image is super(im)posable	1
(a)(v)	M1 hydrolysis M2 esterification / condensation	2
(b)(i)	M1 no. of mol $\text{O}_2 = \frac{1.00 \times 10^5 \times 1.06 \times 10^{-3}}{(8.31 \times 850)}$ M2 no. of mol of nitroglycerine = $4 \times 0.0150 = 0.0600$ (mol) M3 mass of nitroglycerine = $0.0600 \times 227 = 13.6(2)$ (g)	3
(b)(ii)	$1.06 \times 29 = 30.7(4) \text{ dm}^3$	1
(c)(i)	$\text{C}_5\text{H}_8\text{O}_2$	1
(c)(ii)		1
(c)(iii)	 M1 curly arrow from $\text{C}=\text{C}$ double bond to Br M2 correct dipole in Br_2 AND curly arrow from $\text{Br}-\text{Br}$ to $\text{Br}^{\delta-}$ M3 correct intermediate AND curly arrow from lone pair on Br^- to C^+ M4 correct product	4
(d)(i)	M1  M2 (two) different groups on each C atom in the $\text{C}=\text{C}$ / end of the $\text{C}=\text{C}$ double bond M3 no / restricted rotation about $\text{C}=\text{C}$	3
(d)(ii)	H_2 / hydrogen	1
(d)(iii)	M1 / M2 absorptions seen in both spectra (any two): (same) both show an absorption at $1680-1730 \text{ (cm}^{-1}\text{)}$ because of $\text{C}=\text{O}$ (same) both show an absorption at $1040-1300 \text{ (cm}^{-1}\text{)}$ because of $\text{C}-\text{O}$ (same) both show an absorption at $2500-3000 \text{ (cm}^{-1}\text{)}$ because of $\text{RCO}_2\text{-H}$ / O-H in RCO_2H / carboxyl(ic acid) M3 absorption only seen in spectrum of T: (different) T shows an absorption at $1500-1680 \text{ (cm}^{-1}\text{)}$ because of $\text{C}=\text{C}$ (different) T shows an absorption at $3000-3100 \text{ (cm}^{-1}\text{)}$ because of $(\text{C}=\text{C})\text{-H}$	3

139. 9701_s20_ms_21 Q: 5

(a)(i)	Cl	1
(a)(ii)	HCl AND H ₂ O	1
(a)(iii)	M1 CO ₃ ²⁻ M2 propanoic acid – effervesce. (Propan-1-ol – no reaction)	2
(b)(i)	ultraviolet light / uv	1
(b)(ii)	homolytic fission (of chlorine (gas) / Cl ₂)	1
(c)(i)	carbonyl / aldehyde / ketone	1
(c)(ii)	tertiary halogenoalkane	1
(d)(i)	Two structures representing the intermediate M1 C ₂ H ₅ C ⁺ HCH ₃ M2 CH ₃ CH ₂ CH ₂ C ⁺ H ₂	2
(d)(ii)	Identify the most stable intermediate M1 C ₂ H ₅ C ⁺ HCH ₃ explanation M2 (more / 2 alkyl groups attached so) it has the greater inductive / electron donating effect	2

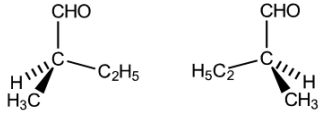
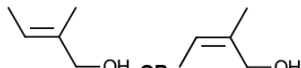
140. 9701_w20_ms_22 Q: 3

(a)(i)	$P_4 + 10Cl_2 \rightarrow 4PCl_5$	1
(a)(ii)	simple / molecular AND covalent	1
(b)(i)	steamy / misty fumes	1
(b)(ii)	$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$	1
(b)(iii)	0 to 4	1
(c)(i)	LiAlH ₄ OR lithium tetrahydridoaluminate(III)	1
(c)(ii)	M1: molecule with a non super-(im)posable mirror image	2
	M2: 	
(c)(iii)		1
(d)(i)	M1: (trigonal) pyramidal	2
	M2: 107	
(d)(ii)	M1: proton / H ⁺ donor	2
	M2: partially dissociates (in solution)	
(d)(iii)	method 1 M1: show the number of mol gas produced from 0.241 g NCl ₃ <i>[M_r(NCl₃) = 120.5 1 mol NCl₃ produces 2 mol gas]</i> $n = 2 \times 0.241 / 120.5$ OR $n = 0.0040$ (mol gas produced.)	4
	M2: correct conversion of T to Kelvin, V to m ³ and correct value of R	
	M3: use of equation $P = nRT / V$ with M2 values for n, R, T and V to find pressure of mol gas produced	
	increase in $p = nRT / V = \frac{0.0040 \times 8.31 \times 293}{250 \times 10^{-6}}$ $= 3.90 \times 10^4$	
	M4: $= 1.00 \times 10^5 + M3$ (Pa) total pressure $= 1.00 \times 10^5 + 3.90 \times 10^4$ $= 1.39 \times 10^5$ (Pa)	
	method 2 M1: calculate the produced from 0.241 g NCl ₃ 0.003 (mol) Cl ₂ AND 0.001 (mol) N ₂ M2: conversion of T to Kelvin, V to m ³ and correct value of R in all PV/RT equations used M3: use of equation $PV / RT = n$ for both calculations or a combined equation with M2 values for R, T and V to find partial pressure for each of the gases $ppCl_2 = 29217.96$ AND $ppN_2 = 9739.32$ M4: Use $P_{total} = pp \text{ unreacted gas} + ppCl_2 + ppN_2$ $1 \times 10^5 + 2.92 \times 10^4 + 9.74 \times 10^3 = 138\,940$	

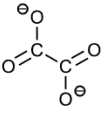
141. 9701_s19_ms_21 Q: 4

(a)	3-chloroprop-1-ene			1								
(b)	a = 109(.5)°			1								
	b = 120°			1								
(c)(i)	C ₃ H ₇ ClO ₂			1								
(c)(ii)	oxidation			1								
(c)(iii)	<table><tr><td></td><td>alcohol group present in Z</td></tr><tr><td>primary</td><td>✓</td></tr><tr><td>secondary</td><td>✓</td></tr><tr><td>tertiary</td><td></td></tr></table>				alcohol group present in Z	primary	✓	secondary	✓	tertiary		1
	alcohol group present in Z											
primary	✓											
secondary	✓											
tertiary												
(d)(i)	A and B			1								
(d)(ii)		Compound(s)	Observation	2								
	Reaction with Tollens' reagent	B ✓	silver mirror OR grey / black / brown / silver precipitate ✓									
		Compound(s)	Observation	3								
	Reaction with alkaline aq. iodine	A ✓ and C ✓	(Pale) yellow precipitate /solid ✓									
		Compound(s)	Observation	3								
	Reaction with sodium metal	C ✓ and D✓	Effervescence / sodium/solid disappears ✓									

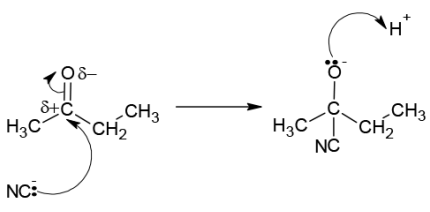
142. 9701_w19_ms_21 Q: 4

(a)(i)	(2,2-)dimethylpropanal	1								
(a)(ii)	sp ²	1								
(b)(i)	acidified potassium dichromate [[VI]] AND heat under reflux	1								
(b)(ii)	M1: A has H-bonding (between molecules) M2: B only has dipole–dipole / VdW forces (between molecules) M3: H-bonding is stronger / requires more energy to overcome	3								
(b)(iii)	(CH ₃) ₃ CCHO + 2[H] → (CH ₃) ₃ CCH ₂ OH	1								
(b)(iv)	 M1: / CH ₃ CH(OH)CH ₃ M2: H ₂ SO ₄ / sulfuric acid	2								
(c)(i)	- orange / red / yellow precipitate - orange / red / yellow precipitate	1								
(c)(ii)	Aldehyde	1								
(c)(iii)	has a carbon / atom attached / bonded to four different atoms / groups / groups of atoms / chains	1								
(c)(iv)	 M1: Correct 3D representation M2: Correct 3D representation of drawn enantiomer	2								
(c)(v)	<table><tr><td>principal absorptions in the infra-red spectrum</td><td>bond responsible</td></tr><tr><td>3200–3600 cm⁻¹</td><td>RO-H / O-H</td></tr><tr><td>1630 cm⁻¹</td><td>C=C</td></tr><tr><td>1050 cm⁻¹</td><td>C—O</td></tr></table>	principal absorptions in the infra-red spectrum	bond responsible	3200–3600 cm ⁻¹	RO-H / O-H	1630 cm ⁻¹	C=C	1050 cm ⁻¹	C—O	1
principal absorptions in the infra-red spectrum	bond responsible									
3200–3600 cm ⁻¹	RO-H / O-H									
1630 cm ⁻¹	C=C									
1050 cm ⁻¹	C—O									
(c)(vi)	 M1: skeletal alkene group AND C5 structure M2: one alcohol group M3: branched chain AND capable of geometrical isomerism	3								
(c)(vii)	M1: Correct structure of X and correct dipole on C=O M2: curly arrow from C=O bond to O AND intermediate with CN attached and –ve charge on the O M3: curly arrow from lone pair on CN ⁻ to C(=O) in X AND curly arrow from lone pair in the intermediate to H ⁺ 	3								
(c)(viii)	catalyst	1								

143. 9701_m18_ms_22 Q: 3

(a)(i)	$\text{Ca} + 2\text{HNO}_3 \rightarrow \text{Ca}(\text{NO}_3)_2 + \text{H}_2$	1						
(a)(ii)	CaSO_4 does not react (with sulfuric acid) coating / crust / protective layer / CaSO_4 prevents reaction (of sulfuric acid) with calcium	2						
(b)(i)	 dot-and-cross diagram AND 2+	1						
(b)(ii)	 displayed structure of ethanedioate two – charges on carboxylates OR 2– charge overall	2						
(c)(i)	bleach	1						
(c)(ii)	$\text{Cl}_2 + 2\text{OH}^- \rightarrow \text{Cl}^- + \text{ClO}^- + \text{H}_2\text{O}$	1						
(c)(iii)	–1 AND (+)5	1						
(c)(iv)	gains AND loses electrons	1						
(d)(i)	carbon dioxide AND water	1						
(d)(ii)	<table border="1"><thead><tr><th>reaction</th><th>reagent(s) and condition(s)</th></tr></thead><tbody><tr><td>1</td><td>HCN ✓ NaCN ✓</td></tr><tr><td>3</td><td>☐ $\text{K}_2\text{Cr}_2\text{O}_7$ ☐ H_2SO_4 / acid / H^+ ☐ (heat under) reflux</td></tr></tbody></table>	reaction	reagent(s) and condition(s)	1	HCN ✓ NaCN ✓	3	☐ $\text{K}_2\text{Cr}_2\text{O}_7$ ☐ H_2SO_4 / acid / H^+ ☐ (heat under) reflux	4
reaction	reagent(s) and condition(s)							
1	HCN ✓ NaCN ✓							
3	☐ $\text{K}_2\text{Cr}_2\text{O}_7$ ☐ H_2SO_4 / acid / H^+ ☐ (heat under) reflux							
(d)(iii)	hydrolysis	1						
(d)(iv)	reducing agent	1						
(d)(v)	has a carbon / C / atom attached to four different groups / atoms / chains OR has no plane / line of symmetry / has non-superimposable images	1						

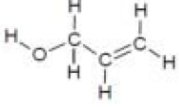
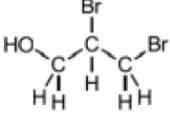
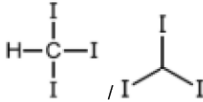
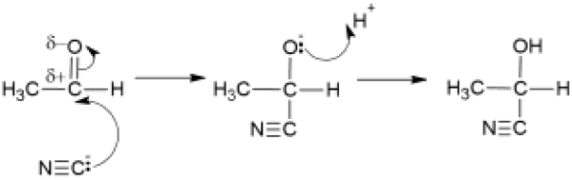
144. 9701_s18_ms_22 Q: 4

(a)(i)	iodoform / tri-iodomethane	1								
(a)(ii)	butanone	1								
(b)	CH ₃ CH ₂ CH ₂ CHO	1								
	(CH ₃) ₂ CHCHO	1								
(c)(i)	reduction	1								
(c)(ii)	NaBH ₄ / sodium borohydride	1								
	OR LiAlH ₄ / lithium aluminium hydride									
(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)	<i>M1 is for the process of taking the % of each element and dividing by its relative atomic mass.</i>									
	<table><tr><td>C</td><td>H</td><td>N</td><td>O</td></tr><tr><td>$\frac{51.3}{12}$</td><td>$\frac{9.40}{1}$</td><td>$\frac{12.0}{14}$</td><td>$\frac{27.3}{16}$</td></tr></table>	C	H	N	O	$\frac{51.3}{12}$	$\frac{9.40}{1}$	$\frac{12.0}{14}$	$\frac{27.3}{16}$	2
	C	H	N	O						
	$\frac{51.3}{12}$	$\frac{9.40}{1}$	$\frac{12.0}{14}$	$\frac{27.3}{16}$						
	OR									
	<table><tr><td>4.28</td><td>9.40</td><td>0.857</td><td>1.71</td></tr></table>	4.28	9.40	0.857	1.71					
	4.28	9.40	0.857	1.71						
	<i>M2 is for dividing the smallest %/A_r into each of the remaining values to produce the correct ratio.</i>									
	<table><tr><td>$\frac{4.28}{0.857}$</td><td>$\frac{9.40}{0.857}$</td><td>$\frac{0.857}{0.857}$</td><td>$\frac{1.71}{0.857}$</td></tr></table>	$\frac{4.28}{0.857}$	$\frac{9.40}{0.857}$	$\frac{0.857}{0.857}$	$\frac{1.71}{0.857}$					
	$\frac{4.28}{0.857}$	$\frac{9.40}{0.857}$	$\frac{0.857}{0.857}$	$\frac{1.71}{0.857}$						
OR										
4.9942 : 10.9685 : 1 : 1.9953										
(e)(ii)	C ₅ H ₁₁ NO ₂ AND because the EFM = RFM	1								

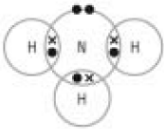
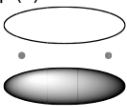
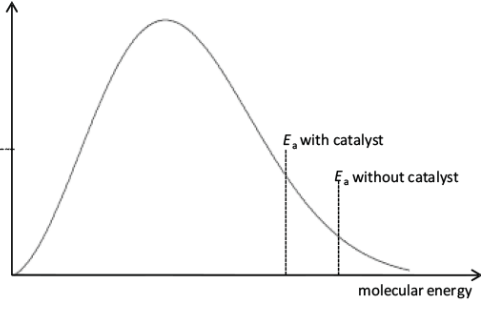
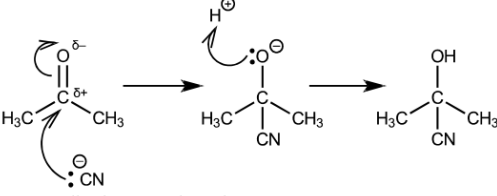
145. 9701_w18_ms_22 Q: 4

(a)(i)		1
(a)(ii)	dehydration	1
(a)(iii)	$\text{H}_3\text{C}-\underset{\text{CO}_2\text{H}}{\overset{\text{OH}}{\text{C}}}-\text{H} + [\text{O}] \rightarrow \text{H}_3\text{C}-\underset{\text{CO}_2\text{H}}{\overset{\text{O}}{\text{C}}}-\text{H} + \text{H}_2\text{O}$	1
(a)(iv)	$\text{Na}_2\text{Cr}_2\text{O}_7 / \text{K}_2\text{Cr}_2\text{O}_7$ AND (dilute) $\text{H}_2\text{SO}_4 / \text{H}^+(\text{aq})$ / acidified	1
(b)(i)	(Molecules that are) non-super(im)posable mirror images	1
(b)(ii)	M1 correct 3-d drawing of one isomer of Q [1] M2 correct pair of 3-d structures of the optical isomers of Q [1]	2
(c)	OR $-\text{CH}_2\text{CH}(\text{CO}_2\text{Na})-$	3
(d)(i)	M1 I experiences a (greater positive) inductive effect due to more alkyl groups OR I contains more electron donating alkyl groups (than II) [1] M2 which stabilises the charge / reduces the charge (on the ion/intermediate) OR spreads the charge across the ion / molecule / intermediate [1]	2
(d)(ii)	M1 curly arrow from double bond to H of H—Br [1] M2 curly arrow from H—Br bond to Br AND correct dipole on H—Br [1] M3 curly arrow from lone pair on Br⁻ to C⁺ [1]	3
(d)(iii)	nucleophilic substitution	1
(e)(i)	$\text{CH}_3\text{COCO}_2\text{H} + 6[\text{H}] \rightarrow \text{CH}_3\text{CHOHCH}_2\text{OH} + \text{H}_2\text{O}$ M1 correct organic product $\text{CH}_3\text{CHOHCH}_2\text{OH}$ [1] M2 [H] present as reactant with H_2O as product and balancing [1]	2
(e)(ii)	$1s^2 2s^2 2p^6 (3s^0)$	1
(e)(iii)	Ions/elements have more shells / energy levels (as the group is descended)	1

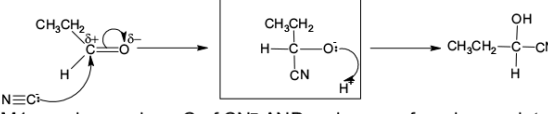
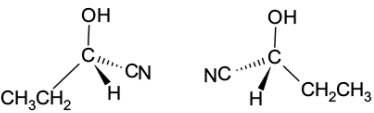
146. 9701_s17_ms_21 Q: 4

(a)(i)	(molecules / isomers with) the same molecular formula / same number of atoms of each element	1
	different structural / displayed formulae / arrangement of bonds	1
(a)(ii)	sp^2 overlap of (2)s with two (2)p (atomic) orbitals	1
	sp^3 overlap of (2)s with all three (2)p (atomic) orbitals	1
(a)(iii)	$sp^2 = 116^\circ - 124^\circ$	1
	$sp^3 = 106^\circ - 112^\circ$	1
(b)(i)		1
(b)(ii)	(electrophilic) addition	1
	bromine decolourises / turns colourless / fades (from orange / brown)	1
(b)(iii)	HOCH ₂ CHBrCH ₂ Br OR 	1
(b)(iv)	CO ₂ / carbon dioxide	1
(c)(i)	P = propanal	1
	Q = propanone	1
(c)(ii)	 tr(i)iodomethane / CHI ₃ /	1
(d)(i)	(molecules / isomers with) the same (molecular and) structural formula	1
	Any two of: chiral centre / C attached to four different groups / atoms non-super(im)posable mirror images different spatial / 3D arrangement of atoms (owtte) different rotation of plane-polarised light	1
(d)(ii)		
	curly arrow from lone pair on :C≡N to C ^(δ+)	1
	correct dipole on carbonyl $\delta^+C=O^{\delta-}$ AND curly arrow from bond to O ^(δ-)	1
	correct intermediate, including C–O ⁻ AND curly arrow from lone pair to H ⁺	1
Total:		19

147. 9701_m16_ms_22 Q: 3

(a) (i)	 three bonding pairs lone pair AND octet shape = (trigonal) pyramidal	[1] [1] [1]
(ii)	sigma(σ) bond  OR  pi(π) bond 	[1] [1]
(b) (i)	forward and backward reactions occurring <u>at same rate</u> OR <u>the rate of</u> forward and backward reactions are equal	[1]
(ii)	M1 = decreased yield of products / less products formed / ora M2 = <u>left</u>-hand side has fewer moles of gas OR equilibrium shifts to the <u>left</u>	[1] [1]
(c)	 M1 = correct Boltzmann curve M2, M3 any 2 from: - line for both E_a values or statement in text that catalyst lowers E_a (catalyst) increases proportion/number of molecules/particles with energy $\geq$ activation energy - so more frequent successful collisions	[1] [1] [1]
(d) (i)	nucleophilic addition	[1]
(ii)	 correct dipole on carbonyl curly arrow from lone pair on CN^- AND from $\text{C}=\text{O}$ to O correct intermediate curly arrow from lone pair on O^- to H^+ correct product	[1] [1] [1] [1] [1]

148. 9701_s16_ms_22 Q: 5

(a) (i)	acidified / H^+ AND potassium/sodium dichromate	[1]
(ii)	distillation (rather than reflux) (ensures aldehyde escapes) to avoid further oxidation/to avoid forming acid/as reflux causes further oxidation	[1] [1]
(b)	reaction 3 – (conc) H_2SO_4 / (conc) H_3PO_4 or Al_2O_3 / pumice / porcelain / porous pot / ceramic AND heat reaction 4 – KBr / $NaBr$ with (conc) H_2SO_4 or (red)P and Br_2 / PBr_3 AND heat	[1] [1]
(c) (i)	 M1 = lone pair on C of CN^- AND curly arrow from lone pair to carbonyl carbon M2 = dipole on $C=O$ AND curly arrow to O from = M3 = intermediate with negative charge M4 = lone pair and curly arrow to H^+	[1] [1] [1] [1]
(ii)		[1+1]
(iii)	attack/attach from either side/above or below/from two directions because the carbonyl/ molecule is planar/trigonal/flat/because of the shape of the molecule OR product is chiral/has a chiral carbon/has a carbon attached to four different groups/has a chiral centre/is asymmetric (equal) chance of forming either (of the two optical isomers)/mechanism doesn't distinguish between the two (optical isomers)/able to form either/chance of forming/able to form 50:50 OR because the carbonyl/ molecule is planar/trigonal/flat OR because of the shape of the molecule (equal) chance of forming either (of the two optical isomers)/mechanism doesn't distinguish between the two (optical isomers)/able to form either/chance of forming/able to form 50:50	[1] [1]

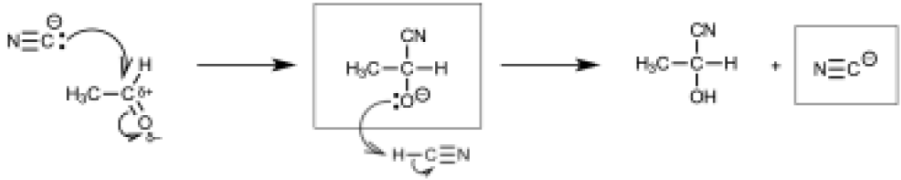
149. 9701_w16_ms_21 Q: 5

(a)		1	1
(b)	$H^+ / Cr_2O_7^{2-}$ (heat under) reflux	1	2
(c)	$H^+ / Cr_2O_7^{2-}$ (heat and) distil	1	2
(d)	(1-)propyl propanoate	1	1
	Total:		6

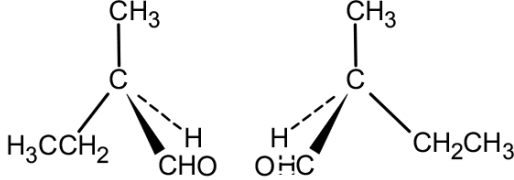
150. 9701_w16_ms_22 Q: 5

(a)(i)	$\text{C}\cdot$ and $\cdot\text{CH}_3$	1
(a)(ii)	Cl^- and $\cdot\text{CH}_3/\text{CH}_3^\cdot$	1
(b)(i)	Oxidation OR reduction	1
(b)(ii)	Condensation	1
(b)(iii)	Reduction OR oxidation OR addition	1
(b)(iv)	Addition	1
Total:		6

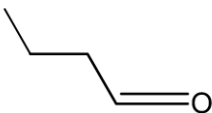
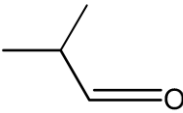
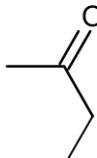
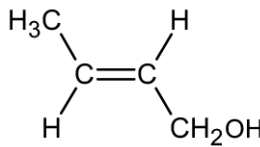
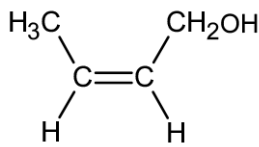
151. 9701_S15_ms_21 Q: 3

(a)	Bond breaking = $\text{C}=\text{O} = 740$ $\text{C}-\text{H} = 410 = 1150 \text{ kJ}$	[1]
	Bond forming = $\text{C}-\text{C} = 350$ $\text{C}-\text{O} = 360$ $\text{O}-\text{H} = 460 = 1170 \text{ kJ}$	[1]
	Enthalpy change = $1150 - 1170 = -20 \text{ kJ mol}^{-1}$	[1]
(b) (i)	Stereoisomerism = (molecules with the same molecular formula and same structural formula but different spatial arrangements of atoms)	[1]
	Chiral centre = atom with four different atoms/groups attached	[1]
(ii)	(Planar) carbonyl so (equal chance of nucleophile) attacking either side	[1]
(c) (i)	 M1 = lone pair AND curly arrow from lone pair to carbonyl C M2 = partial charges on $\text{C}=\text{O}$ AND curly arrow from bond (=) to $\text{O}^{\delta-}$ M3 = structure of intermediate including charge M4 = lone pair AND two correct curly arrows (from lone pair to H AND from $\text{H}-\text{C}$ to C) M5 = CN^-	[1] [1] [1] [1] [1]
(ii)	(CN^- regenerated so) catalyst	[1]

152. 9701_S15_ms_22 Q: 4

(a) (i)	A = $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CHO}$ B = $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CHO}$ C = $(\text{CH}_3)_2\text{CHCH}_2\text{CHO}$ D = $(\text{CH}_3)_3\text{CCHO}$	[1] [1] [1] [1]
(ii)		[1+1]
(b) (i)	Fehling's/Benedict's OR Tollens' OR dichromate OR manganate Warm/heat Fehling's/Benedict's =(Brick)-red ppt Tollens' = silver/mirror OR grey/black precipitate Dichromate = orange to green Manganate = purple to colourless } with the aldehyde/A-D	[1] [1] [1]
(ii)	(2,4-)DNP(H)/Brady's reagent Orange/yellow/red-orange/yellow-orange ppt	[1] [1]

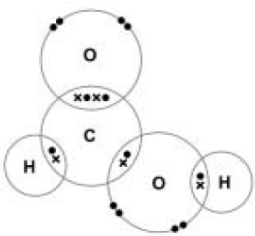
153. 9701_S15_ms_23 Q: 3

(a) (i)	A/B = 		[1]
	C = 		[1]
(ii)	Chain		[1]
(iii)	Silver mirror/ppt/solid (black/grey)		[1]
(b) (i)	D $\text{CH}_2=\text{C}(\text{CH}_3)\text{CH}_2\text{OH}$		[1]
	E  trans OR E	E  cis OR Z	[1+1]
	F $\text{H}_2\text{C}=\text{CHCH}_2\text{CH}_2\text{OH}$		[1]
			[1]
(ii)	Hydrogen		[1]
(c) (i)	$\text{C}_3\text{H}_6\text{O} + [\text{O}] \rightarrow \text{C}_3\text{H}_6\text{O}_2$		[1]
(ii)	$\text{C}_3\text{H}_6\text{O} + 2[\text{H}] \rightarrow \text{C}_3\text{H}_8\text{O}$		[1]

154. 9701_s21_ms_21 Q: 1

Question	Answer	Marks
(a)(i)	option 1 M1 the mass of a molecule OR the (weighted) average / (weighted) mean mass of the molecule(s)	1
	option 1 and M2 relative / compared to 1 / 12 (the mass) of an atom of carbon-12	1
	OR on a scale in which a carbon-12 atom / isotope has a mass of (exactly) 12 (units) option 2 M1 mass of one mol of molecules	
	option 2 M2 relative / compared to 1 / 12 (the mass) of 1 mol of C-12 OR which one mol C-12 (atom / isotope) has a mass of (exactly) 12 g	
(a)(ii)	CO ₂ H	1
(a)(iii)	0.18/90 × 2 × 6.02 × 10 ²³ = 2.408 × 10 ²¹ (atoms) OR 2.4(1) × 10 ²¹ (atoms) M1 no mole ethanedioic acid 0.18 / 90 = 0.0020	1
	M2 no mole ethanedioic acid × 2 0.0020 × 2 = 0.0040	1
	M3 no mole ethanedioic acid × 6.02 × 10 ²³ 2.4 × 10 ²¹	1
(b)(i)	CaC ₂ O ₄ (s) → CaO(s) + CO ₂ (g) + CO(g) M1 correct formulae	1
	M2 balancing equation AND state symbols.	1
(b)(ii)	(thermal) decomposition OR disproportionation	1
(b)(iii)	calcium carbonate / CaCO ₃	1

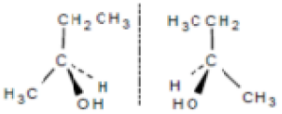
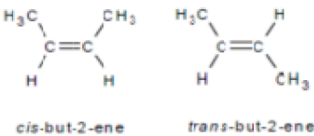
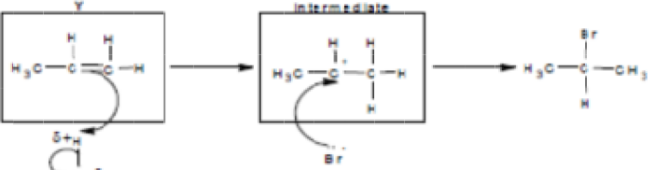
155. 9701_s21_ms_21 Q: 4

Question	Answer	Marks
(a)	Br / bromine as the oxidation number of Br decreases / goes from 0 → -1 OR bromine as it causes oxidation number of C (in methanoic acid) to increase / go from (+)2 → (+)4	1
(b)	(solution) turns (from brown / orange / red to) colourless / decolorises OR brown / orange / red fades	1
(c)(i)	rate = total change in concentration of Br ₂ divided by time taken calculation dependent on graph (100 × 10 ⁻⁵ - 12 × 10 ⁻⁵) / 600 M1 average rate of reaction 1.47 × 10 ⁻⁶	1
	M2 units mol dm ⁻³ s ⁻¹	1
(c)(ii)	graph shown on same axes has steeper initial gradient AND reaches the same final [Br ₂]	1
(c)(iii)	M1 (at increased temp the average kinetic) energy of particles / species / molecules increases.	1
	M2 (many) more/greater proportion of particles with energy ≥ E _a	1
(d)	 M1 correct bonding electrons	1
	M2 correct number of non-bonding electrons around each oxygen	1

156. 9701_s20_ms_22 Q: 5

(a)	<table border="1"> <thead> <tr> <th>Rxn.</th><th>name of mechanism</th><th>Name of reagents and conditions</th></tr> </thead> <tbody> <tr> <td>1</td><td>M1 electrophilic addition</td><td>M2 steam AND concentrated phosphoric acid (catalyst)</td></tr> <tr> <td>2</td><td></td><td>M3 & M4 Two marks for name of reagent and both conditions. One mark for name of reagent and one conditions acidified potassium dichromate ((VI)) condition 1 warm condition 2 distil NOT reflux</td></tr> <tr> <td>6</td><td>M5 nucleophilic substitution</td><td>M6 ammonia (alcoholic) AND heat in a sealed tube / heat under pressure</td></tr> </tbody> </table>	Rxn.	name of mechanism	Name of reagents and conditions	1	M1 electrophilic addition	M2 steam AND concentrated phosphoric acid (catalyst)	2		M3 & M4 Two marks for name of reagent and both conditions. One mark for name of reagent and one conditions acidified potassium dichromate ((VI)) condition 1 warm condition 2 distil NOT reflux	6	M5 nucleophilic substitution	M6 ammonia (alcoholic) AND heat in a sealed tube / heat under pressure	6
Rxn.	name of mechanism	Name of reagents and conditions												
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6	M5 nucleophilic substitution	M6 ammonia (alcoholic) AND heat in a sealed tube / heat under pressure												
(b)(i)	<i>mechanism for ethanal and HCN using CN⁻ (from KCN) as the catalyst</i> M1 arrow from lone pair of electrons on :CN⁻ to C of C=O M2 correct dipole on C^{δ+}=O^{δ-} AND arrow from the double bond to or beyond the O of C=O M3 arrow from lone pair of electrons on O of intermediate to H of HCN AND arrow from H-C bond to C of H-C≡N	3												
(b)(ii)	ALLOW in any order M1 nitrile M2 (secondary) alcohol	2												
(b)(iii)	ALLOW any unambiguous structure	1												

157. 9701_w15_ms_22 Q: 4

(a) (i)	Nucleophilic Substitution	[1]
(ii)	Has a chiral centre / carbon OR has a <u>carbon / C</u> attached to 4 different groups / atoms / chains OR has no plane / line of symmetry	[1]
(iii)		[1+1]
(iv)	Elimination	[1]
(v)		[1] [1]
(vi)	But-1-ene 2 Hs on one of the double-bonded Cs OR does not have 2 different groups on both atoms / each atom in C=C	[1] [1]
(b) (i)	ammonia / NH ₃	[1]
(ii)	propanoyl chloride / C ₂ H ₅ COC ₂ H ₅	[1]
(iii)	CH ₃ CH(NHCOC ₂ H ₅)CH ₃	[1]
(iv)	Reduction LiAlH ₄ / NaBH ₄ / H ₂ and Ni / tin and concentrated HCl	[1] [1]
(v)	aluminium oxide	[1]
(vi)	 M1 = correct structure of Y and curly arrow from double bond to H M2 = dipole and curly arrow from H-Br bond to Br M3 = correct intermediate M4 = Br⁻ with lone pair and curly arrow from lone pair to C(+)	[1] [1] [1] [1]
(vii)	electrophilic addition	[1]
(viii)	secondary carbocation more stable than primary due to electron releasing character / (positive) inductive effect of alkyl groups	[1] [1]

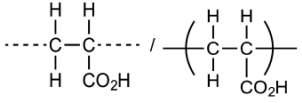
158. 9701_s20_ms_23 Q: 5

(a)(i)	dehydration	1								
(a)(ii)	M1 correct identification of butan-2-ol M2 correct displayed formula including correct connectivity of C–O–H H H H H H C C C H H H O H H H H H	2								
(a)(iii)	<table><tr><td>isomer</td><td>name</td></tr><tr><td>C</td><td>cis but-2-ene</td></tr><tr><td>D</td><td>trans but-2-ene</td></tr><tr><td>E</td><td>but -1-ene</td></tr></table> 2 marks for 3 correct names 1 mark for 2 correct names	isomer	name	C	cis but-2-ene	D	trans but-2-ene	E	but -1-ene	2
isomer	name									
C	cis but-2-ene									
D	trans but-2-ene									
E	but -1-ene									
(b)(i)	<table><tr><td></td><td>Functional group</td></tr><tr><td>F</td><td>M1 Ester / RCOOR⁽¹⁾ / RCO₂R⁽¹⁾</td></tr><tr><td>G</td><td>M2 Carboxyl / carboxylic acid / RCOOH</td></tr><tr><td>H</td><td>M3 Alcohol / hydroxy / R-OH</td></tr></table>		Functional group	F	M1 Ester / RCOOR ⁽¹⁾ / RCO ₂ R ⁽¹⁾	G	M2 Carboxyl / carboxylic acid / RCOOH	H	M3 Alcohol / hydroxy / R-OH	3
	Functional group									
F	M1 Ester / RCOOR ⁽¹⁾ / RCO ₂ R ⁽¹⁾									
G	M2 Carboxyl / carboxylic acid / RCOOH									
H	M3 Alcohol / hydroxy / R-OH									
(b)(ii)	triiodomethane	1								
(b)(iii)	M1 G = HCOOH / HCO ₂ H M2 H = C ₂ H ₅ OH	2								

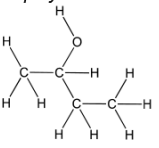
159. 9701_s19_ms_22 Q: 5

(a)(i)	(n-)propyl ethanoate	1						
(a)(ii)	NaOH / sodium hydroxide	1						
a(iii)	<pre> H H H H - C - C - C - O H H H H </pre>	1						
(a)(iv)	perfume / solvent	1						
(b)(i)	M1 divide by <i>A_r</i> <table> <tr> <td>C</td><td>H</td><td>O</td></tr> <tr> <td>54.5 / 12</td><td>9.1 / 1</td><td>36.4 / 16</td></tr> </table>	C	H	O	54.5 / 12	9.1 / 1	36.4 / 16	1
C	H	O						
54.5 / 12	9.1 / 1	36.4 / 16						
	M2 divide by <i>smallest number</i> <table> <tr> <td>4.54 / 2.275 (= 2 OR 1.99)</td><td>9.1 / 2.275(=4)</td><td>2.275 / 2.275 (=1)</td></tr> </table>	4.54 / 2.275 (= 2 OR 1.99)	9.1 / 2.275(=4)	2.275 / 2.275 (=1)	1			
4.54 / 2.275 (= 2 OR 1.99)	9.1 / 2.275(=4)	2.275 / 2.275 (=1)						
	M3 empirical formula based on correctly rounded values of M2 C ₂ H ₄ O	1						
(b)(ii)	(relative) molecular mass / M _r	1						
(c)(i)	C ₃ H ₆ O ₂	1						
(c)(ii)	X and Z – no reaction / no (visible) change	1						
	Y – effervesces	1						
(d)	2HCO ₂ H + Na ₂ CO ₃ → 2HCO ₂ Na + CO ₂ + H ₂ O	1						

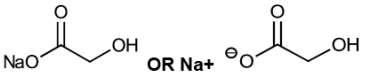
160. 9701_m21_ms_22 Q: 3

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)	<i>displayed formula of butan-2-ol structure with O—H shown</i> 	1
(b)(i)	2-bromobutane	1
(b)(ii)	substitution	1
(b)(iii)	<i>reagent</i> M1 NaCN or KCN	1
	<i>conditions</i> M2 ethanolic AND heat (under reflux)	1
(b)(iv)	$(1)\text{C}_4\text{H}_9\text{CN} + (1)\text{H}^+ + 2\text{H}_2\text{O} \rightarrow (1)\text{C}_4\text{H}_9\text{CO}_2\text{H} + (1)\text{NH}_4^+ \checkmark\checkmark$ <i>correct organic product showing carboxylic acid functional group</i> M1 $\text{C}_4\text{H}_9\text{CO}_2\text{H}$ / $\text{C}_4\text{H}_9\text{COOH}$	1
	M2 balanced equation with a $\text{C}_5\text{H}_{10}\text{O}_2$ or equivalent structure as product	1
(b)(v)	2200–2250 (cm^{-1} due to) $\text{C}\equiv\text{N}$ / triple bond between C and N.	1

162. 9701_w21_ms_21 Q: 4

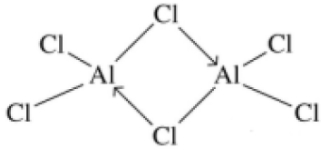
Question	Answer	Marks
(a)(i)	potassium/sodium dichromate [(VI)] / $\text{K}_2\text{Cr}_2\text{O}_7$ / $\text{Na}_2\text{Cr}_2\text{O}_7$ acidified AND (heat) under reflux	2
(a)(ii)	$\text{C}_2\text{H}_5\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{CO}_2\text{H} + \text{H}_2\text{O}$	1
(a)(iii)	substitution	1
(a)(iv)	in the same phase / in same state	1
(b)	M1 ester M2 1100 cm^{-1} linked to $\text{C}-\text{O}$ AND 1720 cm^{-1} linked to $\text{C}=\text{O}$ 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 $(\text{CH}_2\text{OH})_2 + \text{SOCl}_2 \rightarrow (\text{CH}_2\text{Cl})_2 + \text{SO}_2 + \text{H}_2\text{O}$	1
(d)	Forms hydrogen bonds with water	1

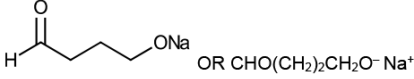
163. 9701_s20_ms_21 Q: 6

(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 , $\text{CH}_3\text{CH}_2\text{COCH}_3$ 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 $1670\text{-}1740\text{ cm}^{-1}$ due to C=O	2
(f)(i)	$\text{CH}_3\text{CH}_2\text{CO}_2\text{H} + 4[\text{H}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{H}_2\text{O}$	1
(f)(ii)	propan-1-ol ALLOW propan-2-ol as error carried forward from 6f(i)	1
(g)(i)	Molecular formula of W $\text{C}_3\text{H}_6\text{O}_2$	1
(g)(ii)	Possible structure of W $\text{CH}_3\text{COOCH}_3$ OR $\text{HCOOCH}_2\text{CH}_3$	1

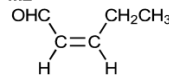
164. 9701_w20_ms_21 Q: 3

(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)	$C_2H_5CH(OH)CN + HCl + 2H_2O \rightarrow C_2H_5CH(OH)COOH + NH_4Cl$	1
(c)(v)	Any two of three absorption references: - absorption $2200-2250\text{ (cm}^{-1}\text{)}$ shows presence of $C\equiv N$ - lack of absorption at $1680-1730\text{ (cm}^{-1}\text{)}$ shows lack of $C=O$ - lack of absorption at $2500-3000\text{ (cm}^{-1}\text{)}$ shows lack of RCO_2H / $O-H$ in RCO_2H	2

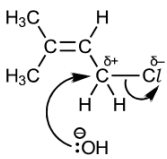
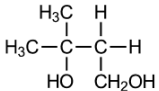
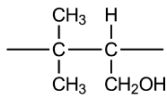
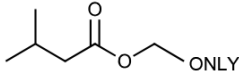
165. 9701_w20_ms_22 Q: 4

(a)(i)	oxidation	1												
(a)(ii)	M1: potassium dichromate[(VI)] M2: acid(ified) AND (heat under) reflux	2												
(a)(iii)	<i>structure of H</i> 	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 M2: G no change AND J yellow ppt	2												
(b)(iii)	reducing agent	1												
(b)(iv)	(1,3-)butadiene OR buta(-1,3-)diene OR 	1												
(c)	<table border="1"> <thead> <tr> <th>reagent</th><th>result with P</th><th>result with Q</th></tr> </thead> <tbody> <tr> <td>Br₂(aq)</td><td>no change / stays orange</td><td>no change / stays orange</td></tr> <tr> <td>2,4-DNPH</td><td>no change</td><td>orange ppt</td></tr> <tr> <td>Na₂CO₃</td><td>effervescence</td><td>no change</td></tr> </tbody> </table> Award one mark for every two correct observations.	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 ₂ CO ₃	effervescence	no change	3
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 ₂ CO ₃	effervescence	no change												
(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												

166. 9701_m19_ms_22 Q: 3

(a)	<table><tr><td></td><td>P</td><td>Q</td><td>R</td></tr><tr><td>Na(s)</td><td>effervescence</td><td>no reaction</td><td>no reaction</td></tr><tr><td>2,4-DNPH</td><td>no reaction</td><td>orange ppt</td><td>orange ppt</td></tr><tr><td>acidified K₂Cr₂O₇(aq)</td><td>no reaction</td><td>no reaction</td><td>(turns) green</td></tr></table>		P	Q	R	Na(s)	effervescence	no reaction	no reaction	2,4-DNPH	no reaction	orange ppt	orange ppt	acidified K ₂ Cr ₂ O ₇ (aq)	no reaction	no reaction	(turns) green	3
	P	Q	R															
Na(s)	effervescence	no reaction	no reaction															
2,4-DNPH	no reaction	orange ppt	orange ppt															
acidified K ₂ Cr ₂ O ₇ (aq)	no reaction	no reaction	(turns) green															
(b)	C ₅ H ₁₀ O + 2[H] → C ₅ H 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																

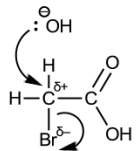
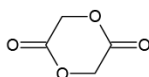
167. 9701_w19_ms_22 Q: 4

(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^{δ-}	2
(b)(i)		1
(b)(ii)	(CH ₃) ₂ CHCH(OH)CH ₂ OH	1
(b)(iii)	optical (isomerism)	1
(b)(iv)	C ₅ H ₁₂ O ₂ + 3[O] → C ₅ H ₈ O ₃ + 2H ₂ O	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 lower (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 HCl propagation 	4
(b)	elimination	1
(c)(i)	acidified AND KMnO_4 hot AND <u>c</u> (oncentrated)	2
(c)(ii)	cyclohexene would have absorption at $1500\text{--}1680\text{ cm}^{-1}$ because of $\text{C}=\text{C}$ (and adipic acid would not) cyclohexene would have absorption at $3000\text{--}3100\text{ cm}^{-1}$ because of $=\text{C}\text{--H}/\text{C}\text{--H}$ in alkene (and adipic acid would not) adipic acid would have absorption at $2500\text{--}3000\text{ cm}^{-1}$ because of $\text{O}\text{--H}/\text{CO}_2\text{--H}$ (and cyclohexene would not) adipic acid would have absorption at $1040\text{--}1300\text{ cm}^{-1}$ because of $\text{C}\text{--O}$ (and cyclohexene would not) adipic acid would have absorption at $1640\text{--}1750\text{ cm}^{-1}$ because of $\text{C}=\text{O}$ (and cyclohexene would not)	max 3

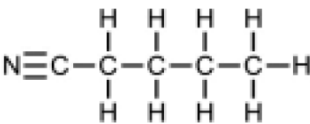
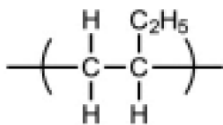
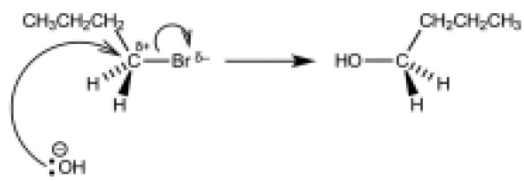
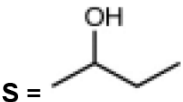
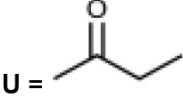
169. 9701_w18_ms_21 Q: 4

(a)	<table><tr><th>reagent</th><th>observation with glycolic acid</th><th>does a reaction occur? ✓ / x</th><th>functional group</th></tr><tr><td>Na₂CO₃(aq)</td><td>effervescence / fizzing / bubbling</td><td>✓</td><td>COOH / carboxylic acid</td></tr><tr><td>2,4–DNPH</td><td>no visible reaction owtte</td><td>x</td><td>(no group required)</td></tr><tr><td>acidified Cr₂O₇²⁻</td><td>orange to green</td><td>✓</td><td>–OH / alcohol</td></tr></table> 1 mark for each in column 2 (obs) 1 mark for COOH and OH	reagent	observation with glycolic acid	does a reaction occur? ✓ / x	functional group	Na ₂ CO ₃ (aq)	effervescence / fizzing / bubbling	✓	COOH / carboxylic acid	2,4–DNPH	no visible reaction owtte	x	(no group required)	acidified Cr ₂ O ₇ ²⁻	orange to green	✓	–OH / alcohol	4
reagent	observation with glycolic acid	does a reaction occur? ✓ / x	functional group															
Na ₂ CO ₃ (aq)	effervescence / fizzing / bubbling	✓	COOH / carboxylic acid															
2,4–DNPH	no visible reaction owtte	x	(no group required)															
acidified Cr ₂ O ₇ ²⁻	orange to green	✓	–OH / alcohol															
(b)(i)	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{C}\equiv\text{N} \\ \\ \text{OH} \end{array}$	1																
(b)(ii)	hydrochloric / sulfuric / nitric / phosphoric acid	1																
(b)(iii)	free-radical substitution	1																
(b)(iv)	UV (light) / sunlight	1																
(b)(v)	 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	2																
(c)(i)	reducing agent / reductant	1																
(c)(ii)	C ₂ H ₂ O ₃ + 2[H] → C ₂ H ₄ O ₃ M1 for correct molecular formulae C ₂ H ₂ O ₃ and C ₂ H ₄ O ₃ M2 for balancing	2																
(d)(i)	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	2																
(d)(ii)	 M1 ANY ester group AND valid C₄H₄O₄ molecule M2 correct cyclic structure	2																

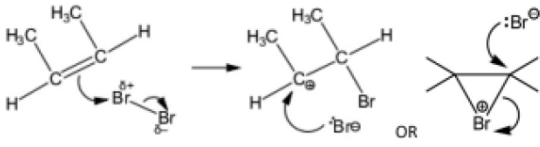
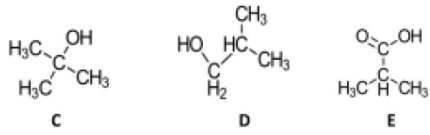
170. 9701_w18_ms_22 Q: 3

(a)	$\Delta H_r = (-692.9) + 3(-61.8) - (-182.1) - 3(-204.6)$ $= -82.4 \text{ (kJ mol}^{-1}\text{)}$ M1 $\Delta H_r = x(-692.9) + y(-61.8) - v(-182.1) - w(-204.6)$ 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 <u>repulsive</u> forces between particle / molecules become significant	2
(c)(i)	$\text{CHCl}_3 + \frac{1}{2}\text{O}_2 \rightarrow \text{COCl}_2 + \text{HCl}$	1
(c)(ii)	M1 X marked on peak at $1670\text{--}1740 \text{ cm}^{-1}$ [1] M2 CHCl_3 has no C=O [1]	2
(c)(iii)	(It / CHCl_3 has a) peak at $2850\text{--}2950 \text{ (cm}^{-1}\text{)}$ OR carbonyl dichloride spectrum has no peak $2850\text{--}2950 \text{ (cm}^{-1}\text{)}$	1

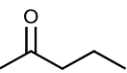
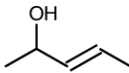
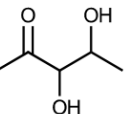
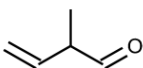
171. 9701_m17_ms_22 Q: 3

(a)(i)		1
(a)(ii)	reaction 1 = HCl(aq)	1
	reaction 2 = (conc.) NaOH/KOH AND ethanol	1
(a)(iii)		2
	C–C backbone with dangling bonds rest of structure	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)		1
		1
		1
(c)(v)	$\text{CH}_3\text{CHOHCH}_2\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_2\text{CH}_3 + \text{H}_2\text{O}$	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

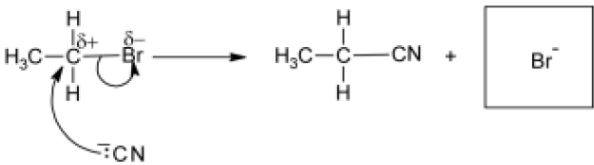
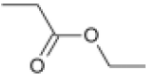
172. 9701_s17_ms_22 Q: 4

(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 ₃ CHCHCH ₃ OR CH ₃ CH=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)		1
	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 ^{δ-}	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) ₃ COH / any unambiguous structure	1
	D = (2-)methylpropan-1-ol / (CH ₃) ₂ CHCH ₂ OH / any unambiguous structure	1
	E = (2-)methylpropanoic acid / (CH ₃) ₂ CHCO ₂ H / any unambiguous structure	1
		
(b)(ii)	2C ₄ H ₈ O ₂ + Na ₂ CO ₃ → 2C ₄ H ₇ O ₂ Na + H ₂ O + CO ₂	1
(c)(i)	triiodomethane	1
(c)(ii)	F = CH ₃ CH ₂ CH ₂ COCH ₃	1
	G = C ₂ H ₅ CH(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)	<i>This question was discounted.</i> M1 = decolourises bromine / $1500\text{--}1600\text{ cm}^{-1}$ = alkene M2 = absorption at 1700 cm^{-1} is C=O AND (very) broad absorption at $2500\text{--}3000\text{ cm}^{-1}$ 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]

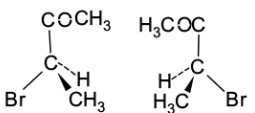
174. 9701_s16_ms_21 Q: 5

(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	[1] [1]
	OR peak at 3200–3650 due to (alcohol) O—H (formation)	[1] [1]
(c) (i)	sodium/potassium hydroxide aqueous	[1] [1]
(ii)	ethanol	[1]
(d) (i)	(conc) H ⁺ / (conc) acid / (conc) H ₂ SO ₄ / (conc) H ₃ PO ₄	[1]
(ii)		[1]
(iii)	ethyl propanoate	[1]
(e) (i)	V = CH ₃ CH ₂ CHCHCH ₂ CH ₃ / CH ₃ CH ₂ CH=CHCH ₂ CH ₃ T = CH ₃ CH ₂ CH(OH)CH(OH)CH ₂ CH ₃	[1] [1]
	(ii) V = geometric(al) / <i>cis-trans</i> / <i>E-Z</i> T = optical	[1] [1]

175. 9701_s16_ms_22 Q: 4

(a)	CH ₃ CH ₂ CH ₂ COOH	[1]
	(CH ₃) ₂ CHCOOH / CH ₃ CH(CH ₃)COOH	[1]
(b) (i)	Two from 1. CH ₃ CH ₂ COOCH ₃ 2. CH ₃ COOCH ₂ CH ₃ 3. HCOOCH ₂ CH ₂ CH ₃	[1] [1]
(ii)	correct acid + alcohol for either ester 1. methanol + propanoic acid 2. ethanol + ethanoic acid 3. propan-1-ol + methanoic acid	[1]
	(conc) H ₂ SO ₄ / (conc) H ₃ PO ₄ AND heat / warm / reflux	[1]
(c)	Peak at 1710–1750 (for ester) due to C(=)O	[1]
	Peak at 1500–1680 (for X) due to C(=)C / alkene	[1]
	Peak at 3200–3650 (for X) due to (alcohol) O(–)H	[1]

176. 9701_s16_ms_23 Q: 4

(a)	3-hydroxybutan(-2)-one	[1]
(b)	H ₂ /Cr ₂ O 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 ₃ COCH(=)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)	<table><tr><td>particle</td><td>relative mass</td><td>relative charge</td><td>location</td><td>total number in an atom of ¹⁹⁷Au</td></tr><tr><td>electron</td><td>0.0005</td><td>−1</td><td>shell(s) [1]</td><td>79</td></tr><tr><td>neutron</td><td>1.(001) [1]</td><td>0 [1]</td><td>nucleus</td><td>118 [1]</td></tr></table>					particle	relative mass	relative charge	location	total number in an atom of ¹⁹⁷ Au	electron	0.0005	−1	shell(s) [1]	79	neutron	1.(001) [1]	0 [1]	nucleus	118 [1]	4
	particle	relative mass	relative charge	location	total number in an atom of ¹⁹⁷ Au																
	electron	0.0005	−1	shell(s) [1]	79																
	neutron	1.(001) [1]	0 [1]	nucleus	118 [1]																
(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															