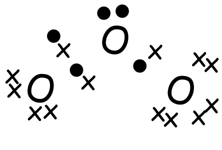
Past Papers
Advanced Higher Chemistry

2013
Marking Scheme

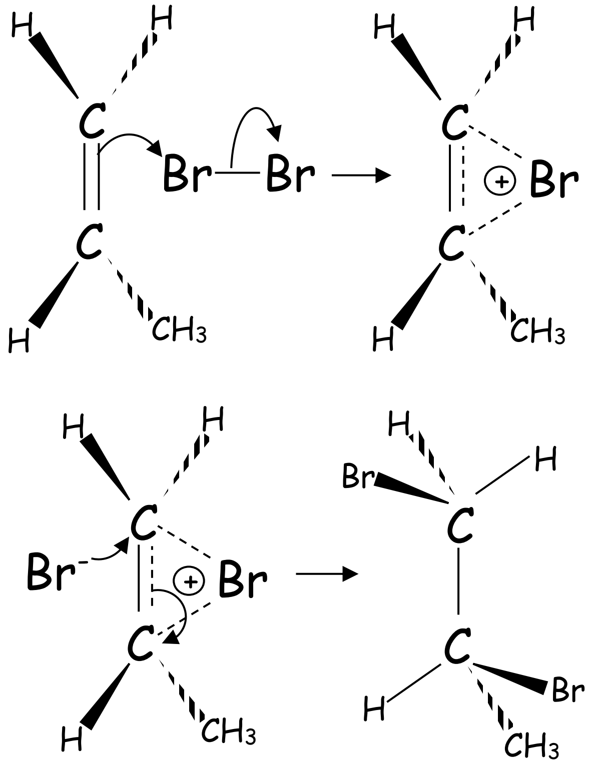
Grade Awarded	Mark Required		% candidates achieving grade
	(/125)	%	
A	87+	69.6%	31.6%
B	74+	59.2%	26.6%
C	61+	48.8%	21.4%
D	54+	43.2%	9.9%
No award	<54	<43.2%	12.1%

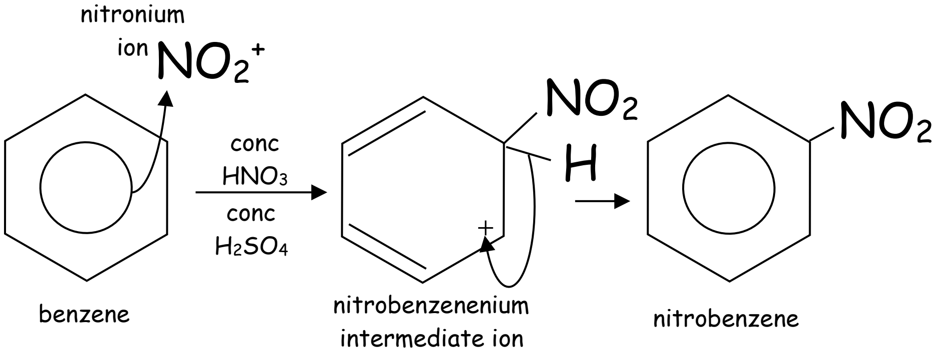
Section:	Multiple Choice	Extended Answer	Investigation
Average Mark:	28.0 /40	33.5 /60	15.2 /25

2013 Adv Higher Chemistry Marking Scheme

<table>
<tr><th>MC Qu</th><th>Answer</th><th>% Pupils Correct</th><th>Reasoning</th></tr>
<tr><td>1</td><td>C</td><td>90</td><td>☒A Each Ionisation Energy removes only one mole of electrons
☒B Each Ionisation Energy removes only one mole of electrons
☑C Removal of one mole of electrons from one mole of 1+ gaseous ions
☒D Each Ionisation Energy removes only one mole of electrons</td></tr>
<tr><td>2</td><td>B</td><td>77</td><td>
<table>
<tr><td>EM Radiation</td><td>Gamma</td><td>X-ray</td><td>UV</td><td>Visible</td><td>Infrared</td><td>Microwave</td><td>Radio & TV</td></tr>
<tr><td>Velocity</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td></tr>
<tr><td>Wavelength</td><td>short</td><td colspan="5">⟶</td><td>Long</td></tr>
<tr><td>Frequency</td><td>high</td><td colspan="5">⟵</td><td>Low</td></tr>
</table>
</td></tr>
<tr><td>3</td><td>A</td><td>74</td><td>☑A Copper (II) Sulphate gives blue-green flame colour (λ=325nm) ∴ highest frequency
☒B Potassium Chloride gives lilac flame colour (λ=405nm)
☒C Barium Chloride gives green flame colour (λ=554nm)
☒D Lithium Sulphate gives crimson flame colour (λ=671nm) ∴ lowest frequency</td></tr>
<tr><td>4</td><td>D</td><td>62</td><td>
<table>
<tr><td>Colour</td><td>Violet</td><td>Indigo</td><td>Blue</td><td>Green</td><td>Yellow</td><td>Orange</td><td>Red</td></tr>
<tr><td>Velocity</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td><td>$3\times10^{8} m\ s^{-1}$</td></tr>
<tr><td>Wavelength</td><td>450nm</td><td colspan="5">⟷</td><td>700nm</td></tr>
<tr><td>Frequency</td><td>6.67×10^{14}Hz</td><td colspan="5">⟷</td><td>4.28×10^{14}Hz</td></tr>
<tr><td>Indicator Colour</td><td>A in acid
C in alkali</td><td></td><td>B in alkali</td><td>B in acid</td><td>C in acid
D in alkali</td><td></td><td>A in alkali
D in acid</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>D</td><td>70</td><td>☒A Pauli Exclusion Principle: No electron has the same 4 quantum numbers
☒B Heisenberg Uncertainty: momentum and position of an electron cannot be defined at same instant
☒C Aufbau principle: Orbitals fill up in order of lowest energy (1s,2s,2p,3s,3p,4s,3d,4p,5s,4d,5p,6s,4f, etc)
☑D Hund's Rule: orbitals fill up single rooms first to maximise the number of parallel spins</td></tr>
<tr><td>6</td><td>A</td><td>62</td><td>☑A 3 electrons in 3rd shell ∴ element is in group 3
☒B 5 electrons in 3rd shell ∴ element is in group 5
☒C Incomplete d-shell ∴ element is a transition metal
☒D 5 electrons in 4th shell ∴ element is in group 5</td></tr>
<tr><td>7</td><td>C</td><td>60</td><td>☒A Mass Spectroscopy: mass measured by the bending of charged particles in electric field
☒B IR-spectroscopy: absorbed IR radiation of particular wavenumber vibrates particular bonds
☑C Emission Spectroscopy: measuring wavelengths produced as excited electrons drop down energy levels
☒D Proton NMR: flipping of hydrogen nuclei in a strong magnetic field using radio waves</td></tr>
<tr><td>8</td><td>A</td><td>61</td><td>☑A Molecule is Ozone $O=O^{+}-O^{-}$
☒B Oxygen atom on right has 10 electrons
☒C Centre oxygen atom has 10 electrons
☒D Molecule is not Ozone $O=O^{+}-O^{-}$
 </td></tr>
<tr><td>9</td><td>C</td><td>78</td><td>☒A NH_3 contains 3 bonding pairs (N-H bonds) and a lone pair of electrons on the nitrogen
☒B NCl_3 contains 3 bonding pairs (N-Cl bonds) and a lone pair of electrons on the nitrogen
☑C NH_4^+ ions contain a dative covalent bond (lone pair provides both electrons in bond)
☒D CH_2NH_2 contains 3 bonding pairs and a lone pair of electrons on the nitrogen</td></tr>
<tr><td>10</td><td>B</td><td>79</td><td>☒A 2 lone pairs (both on oxygen atom)
☑B 3 lone pairs (all on chlorine atom)
☒C 1 lone pairs (on nitrogen atom)
☒D 2 lone pairs (both on oxygen atom)</td></tr>
<tr><td>11</td><td>C</td><td>63</td><td>☒A SF_4 has 5 pairs (4 bonding and 1 non-bonding)
☒B NH_4^+ has 4 pairs (4 bonding and 0 non-bonding) ∴ tetrahedral
☑C XeF_4 has 6 pairs (4 bonding and 2 non-bonding) ∴ square planar
☒D AlH_4^- has 4 pairs (4 bonding and 0 non-bonding) ∴ tetrahedral</td></tr>
</table>

12	C	82	☒A Metal conductivity decreases as temperature rises ☒B Ionic solids do not conduct in the solid state so conductivity will remain zero ☑C Semiconductor conductivity increases as temperature rises ☒D Superconductor conductivity decreases as temperature rises
13	D	76	☒A NH_3 contains polar covalent bonds and is not ionic ☒B HCl is a polar covalent gas and forms hydrogen H^+ ions on dissolving in water ☒C H_2S is a covalent molecule due to similar electronegativities of H and S ☑D $Ca^{2+}(H^-)_2$ is ionic and contains hydride H^- ions
14	B	69	☒A Cu^{2+} ions → Cu metal (oxidation state: 2→0) ☑B Cu^{2+} ions → Cu^{2+} ions in a complex with NH_3 (oxidation state: 2→2) ☒C Cu^{2+} ions → Cu^+ ions (oxidation state: 2→1) ☒D Cu metal → Cu^{2+} ions (oxidation state: 0→2)
15	A	51	Ag^+ ion **no.** of mol = **v**olume x **c**oncentration = 0.1litres x 0.500mol l^{-1} = 0.05mol $\begin{array}{ccccc} Ag^+_{(aq)} & + & Cl^-_{(aq)} & \longrightarrow & AgCl_{(s)} \\ 1mol & & & & 1mol \\ 0.05mol & & & & 0.05mol \end{array}$ 1mol AgCl = 107.9+35.5 = 143.4g **mass** = **no.** of mol x **gfm** = 0.05mol x 143.4g = 7.17g
16	C	46	**no.** of mol = **v**olume x **c**oncentration = 1litre x 0.01mol l^{-1} = 0.01mol 1x $Ni(H_2O)_6.K_2(SO_4)_2$ contains 1x$Ni(H_2O)_6$ ion complex, 2xK^+ ions & 2xSO_4^{2-}ions = 5 ions ∴0.01mol of $Ni(H_2O)_6.K_2(SO_4)_2$ contains 0.05mol of ions
17	B	54	**no.** of mol K^+ ions = **v**olume x **c**oncentration = 1 litre x 0.1 mol l^{-1} = 0.1 mol K^+ ions 1 mol K_2SO_4 contains 2 mol K^+ ions ∴ 0.05 mol K_2SO_4 contains 0.1 mol K^+ ions $\text{volume} = \frac{\textbf{no.}\text{ of mol}}{\textbf{c}\text{oncentration}} = \frac{0.05\text{ mol}}{0.2\text{ mol l}^{-1}} = 0.25\text{ litres} = 250cm^3$
18	C	80	☒A Catalysts do not alter the position of equilibrium ☒B Adding acid will move equilibrium to left to remove the additional product (H^+) ☑C OH^- ions neutralise H^+ ions and equilibrium will move to right to replace H^+ ions ☒D Adding dihydrogenphosphate ions ($H_2PO_4^-$) will move equilibrium to left
19	A	91	☑A increasing temperature alters the solubilities of caffeine in each solvent differently ☒B adding more caffeine will not alter the proportion of caffeine in the solvents ☒C increasing the volume of a solvent does not alter the final concentration of caffeine ☒D increasing the volume of a solvent does not alter the final concentration of caffeine
20	D	85	$\text{partition coefficient} = \frac{[X]_{hexane}}{[X]_{water}} = \frac{13}{6} = 2.17$
21	B	72	☒A pH of ethanoic acid will increase towards pH=7 during dilution ☑B $[H^+]$ will decrease and pH increases towards pH=7 during dilution ☒C pK_a is a measure of the degree of dissociation and dilution does not alter pK_a ☒D Dilution does not alter the degree of dissociation
22	D	71	Ethanoate CH_3COO^- ions join up with H^+ ions and form molecules of ethanoic acid CH_3COOH as ethanoic acid is a weak acid. The removal of H^+ ions from the equilibrium will result in the equilibrium moving to left to replace these H^+ ions and this results in more reverse reaction and less products in the mixture (∴less iodine)
23	A	81	Potassium hydroxide and ethanoic acid will neutralise to form potassium ethanoate and will have an alkaline pH. The indicator chosen should have a pH range which changes colour in the alkaline region of the pH scale.
24	B	76	☒A s-r = difference in activation between uncatalysed and catalysed reactions ☑B p+s = activation energy for the reverse uncatalysed reaction ☒C q-p = activation energy for the forward catalysed reaction ☒D p+r = activation energy for the reverse catalysed reaction
25	B	46	$\Delta H = \Sigma(\text{bonds broken}) - \Sigma(\text{bonds formed})$ $\Delta H = 12\text{x } X\text{-}X \text{ bonds} - 4\text{x } X{\equiv}X \text{ bonds}$ $\Delta H = 12\text{x } 163 - 4\text{x } 944$ $\Delta H = 1956 - 3776$ $\Delta H = -1820 \text{ kJ mol}^{-1}$

26	C	51	❶ $2C(s) + 2H_2(g) \rightarrow C_2H_4(g)$ Enthalpy of formation for ethane **(data required)** ❷ $C(s) \rightarrow C(g)$ Enthalpy of atomisation **(data required)** ❸ $H_2(g) \rightarrow 2H(g)$ Bond Enthalpy for H_2 **(data required)** ❶x-1 $C_2H_4(g) \rightarrow 2C(s) + 2H_2(g)$ ❷x2 $C(s) \rightarrow C(g)$ ❸x2 $H_2(g) \rightarrow 2H(g)$ ❶'+❷'+❸' $C_2H_4(g) \rightarrow 2C(g) + 4H(g)$ Equals the bond enthalpies for: 4xC-H **(data required)** + 1xC=C to be calculated
27	B	87	☒A Gas turning into solid = decrease in disorder ∴ decrease in entropy ☑B Combustion into gas products = increase in disorder ∴ increase in entropy ☒C 2 reactants becoming one product = decrease in disorder ∴ decrease in entropy ☒D many monomers →one polymer = decrease in disorder ∴ decrease in entropy
28	D	57	☒A mpt NaCl = 801°C ∴ NaCl is a solid at 750°C ∴ solid have lower disorder/entropy ☒B mpt $CaCl_2$ = 775°C ∴ $CaCl_2$ is a solid at 750°C ∴ solid have lower disorder/entropy ☒C mpt KCl = 770°C ∴ KCl is a solid at 750°C ∴ solid have lower disorder/entropy ☑D mpt $MgCl_2$= 714°C ∴ $MgCl_2$ is a liquid at 750°C ∴ liquids have higher disorder/entropy
29	D	82	Oxidation is one of the following reactions: primary alcohol $\longrightarrow$ aldehyde $\longrightarrow$ carboxylic acid secondary alcohol $\longrightarrow$ ketone $\not\longrightarrow$ tertiary alcohol $\not\longrightarrow$ Butan-1-ol is a primary alcohol and butanoic acid is a carboxylic acid. Reduction is the reverse reaction of oxidation.
30	A	87	❶ Substitution Reaction $CH_3CH_2CH_2OH \rightarrow CH_3CH_2CH_2Cl$ (Propan-1-ol → 1-chloropropane) ❷ Elimination of HCl $CH_3CH_2CH_2Cl \rightarrow CH_3CH{=}CH_2$ (1-chloropropane → propene) ❸ Substitution of CH_3O^- $CH_3CH_2CH_2Cl \rightarrow CH_3CH_2CH_2OCH_3$ (1-chloropropane → methoxypropane)
31	D	79	

<table>
<tr><td>32</td><td>A</td><td>93</td><td>☑A Initiation Step: Free radicals formed in reaction and found after the arrow
☒B Termination Step: free radicals joining up to form a molecule
☒C Propagation Step: Chain reaction with free radicals being used up and created
☒D Propagation Step: Chain reaction with free radicals being used up and created</td></tr>
<tr><td>33</td><td>B</td><td>77</td><td>☒A Pentanal C_4H_9CHO does not contain hydrogen bonding ∴ lower bpt
☑B Pentan-2-ol $CH_3CH(OH)C_3H_7$ contains hydrogen bonding ∴ highest bpt
☒C Pentan-2-one $CH_3COC_3H_7$ does not contain hydrogen bonding ∴ lower bpt
☒D Ethoxypropane $C_2H_5OC_3H_7$ does not contain hydrogen bonding ∴ lower bpt</td></tr>
<tr><td>34</td><td>D</td><td>79</td><td>
<table>
<tr><td>Answer</td><td>A</td><td>B</td><td>C</td><td>D</td></tr>
<tr><td>Homologous Series</td><td>Alkanal
(Aldehydes)</td><td>Alkanoic Acid
(Carboxylic Acids)</td><td>Alkanols
(Alcohols)</td><td>Ethers</td></tr>
<tr><td>Example</td><td>Propanal
$C_2H_5CHO = C_3H_6O$</td><td>Propanoic acid
$C_2H_5COOH = C_3H_6O_2$</td><td>Propan-1-ol
$C_3H_7OH = C_3H_8O$</td><td>Methyoxyethane
$CH_3OC_2H_5 = C_3H_8O$</td></tr>
<tr><td>Correct General Formula</td><td>$C_nH_{2n}O$</td><td>$C_nH_{2n}O_2$</td><td>$C_nH_{2n+2}O$</td><td>$C_nH_{2n+2}O$</td></tr>
</table>
</td></tr>
<tr><td>35</td><td>D</td><td>61</td><td>Propan-2-ol $CH_3CH(OH)CH_3$ ∴ R group = $-CH(CH_3)CH_3$
2-chlorobutane $CH_3CHClCH_2CH_3$ ∴ R' group = $-CH(CH_3)CH_2CH_3$
∴ Ether R—O—R' = $CH_3CH(CH_3)-O-CH(CH_3)CH_2CH_3$</td></tr>
<tr><td>36</td><td>C</td><td>63</td><td>☒A alcohols are neutral pH=7 ∴ not strongest base
☒B phenol is acidic ∴ not strongest base
☑C primary amines are alkaline and a stronger base than phenylamine $C_6H_5NH_2$
☒D electrons in lone pair on N in $C_6H_5NH_2$ are drawn to delocalised π-electrons in benzene ring making lone pair electrons less likely to be donated to form dative covalent bond</td></tr>
<tr><td>37</td><td>D</td><td>28</td><td>$$\underset{\text{phenylamine}}{C_6H_5NH_2} + HCl \longrightarrow \underset{\text{phenylammonium chloride}}{C_6H_5NH_3^+Cl^-}$$</td></tr>
<tr><td>38</td><td>B</td><td>61</td><td>Nitronium ion formed by: $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$
 </td></tr>
<tr><td>39</td><td>A</td><td>50</td><td>☑A Addition: small molecules added across C=C bonds and other π-bonds
☒B Oxidation: increase in the oxygen:hydrogen ratio
☒C Elimination: small molecule removed (e.g. H_2O) and C=C bond left behind
☒D Substitution: swapping of atoms/groups on and off a molecule</td></tr>
<tr><td>40</td><td>D</td><td>93</td><td>☒A Nucleophiles are species which are attracted to centres of positive charge
☒B Electrophiles are species which are attracted to centres of negative charge
☒C Free Radicals are species with unpaired electrons
☑D Receptors are proteins embedded in cell walls with specific shapes to fit molecules with the correct pharmacophore shape</td></tr>
</table>

2013 Adv Higher Chemistry Marking Scheme

<table>
<tr><th>Long Qu</th><th>Answer</th><th>Reasoning</th></tr>
<tr><td>1a</td><td>Any group 3 element
e.g. B, Al, Ga, In, Tl</td><td><table><tr><th>Semiconductor</th><th>Doped With</th><th>Description</th></tr><tr><td>p-type</td><td>Group 3 element</td><td>Positive hole can migrate across semiconductor</td></tr><tr><td>n-type</td><td>Group 5 element</td><td>5th electron can migrate across semiconductor</td></tr></table></td></tr>
<tr><td>1b</td><td>Positive hole</td><td>The group 3 element has three outer electrons and there is a positive hole left in the space where the 4th bond would be in the semiconductor.</td></tr>
<tr><td>2a</td><td>-220.3 J K^{-1} mol^{-1}</td><td>$$\begin{array}{lccc}\Delta S^{o} & = & \Sigma S^{o}_{(products)} & - & \Sigma S^{o}_{(reactants)}\\ & = & (2x27.0) + (1x5.70) & - & ((2x33.0)+(1x214))\\ & = & 54.0 + 5.7 & - & (66.0 + 214)\\ & = & 59.7 & - & 280\\ & = & -220.3\ J\ K^{-1}\ mol^{-1} & & \end{array}$$</td></tr>
<tr><td>2b</td><td>-526.4 kJ mol^{-1}</td><td>❶ $Mg_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow MgO_{(s)}$ $\Delta H=-493\ kJ\ mol^{-1}$
❷ $C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)}$ $\Delta H=-394\ kJ\ mol^{-1}$
❶x2 $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$ $\Delta H=-986\ kJ\ mol^{-1}$
❷x-1 $CO_{2(g)} \rightarrow C_{(s)} + O_{2(g)}$ $\Delta H=+394\ kJ\ mol^{-1}$
❶' + ❷' $2Mg_{(s)} + CO_{2(g)} \rightarrow 2MgO_{(s)} + C_{(s)}$ $\Delta H=-592\ kJ\ mol^{-1}$
$$\begin{aligned}\Delta G^{o} &= \Delta H^{o} - T\Delta S^{o}\\ &= (-592) - 298 \times {}^{-220.3}/_{1000}\\ &= (-592) - (-65.6)\\ &= -526.4\ kJ\ mol^{-1}\end{aligned}$$</td></tr>
<tr><td>3a</td><td>$Rb_{(s)} + \frac{1}{2}Cl_{2(g)} \rightarrow RbCl_{(s)}$</td><td>Enthalpy of Formation:
The enthalpy change for the formation of 1 mole of a substance from its elements in there natural state</td></tr>
<tr><td>3b</td><td>-349 kJ mol^{-1}</td><td>1st Electron Affinity of Chlorine: $Cl_{(g)} + e^{-} \rightarrow Cl^{-}_{(g)}$</td></tr>
<tr><td>3c</td><td>(Enthalpy of)
Lattice Formation</td><td>Acceptable answers include:<table><tr><td>(enthalpy of) lattice formation</td><td>Lattice</td><td>Lattice energy</td><td>Crystal Lattice</td></tr></table></td></tr>
<tr><td>3d</td><td>-697.5 kJ mol^{-1}</td><td>$$\begin{array}{ccccccccccc}\Delta H_6 & = & \Delta H_1 & + & \Delta H_2 & + & \Delta H_3 & + & \Delta H_4 & + & \Delta H_5\\ \text{Enthalpy of Formation of RbCl} & = & \text{Enthalpy of sublimation of Rb} & + & \text{Bond enthalpy of Cl-Cl} & + & \text{1st Ionisation energy of Rb} & + & \text{Electron Affinity of Cl} & + & \text{Lattice Enthalpy of RbCl}\\ -435 & = & 81 & + & 121.5 & + & 409 & + & (-349) & + & \Delta H_5\\ -435 & = & & & 262.5 & & & & & + & \Delta H_5\end{array}$$
$\Delta H_5 = -435 - 262.5 = -697.5\ kJ\ mol^{-1}$</td></tr>
<tr><td>4a</td><td>Answer to include:</td><td>A series of standard solutions of different known concentrations of potassium permanganate are made up and their absorbencies measured.</td></tr>
<tr><td>4b</td><td>Green or 500-560nm</td><td>The solutions appear purple as the green light is removed by atomic adsorption and the red and blue light is transmitted giving a purple colour.</td></tr>
<tr><td>4c</td><td>Nitrogen dioxide</td><td>Also acceptable: dinitrogen tetroxide, nitrogen monoxide (nitric oxide)</td></tr>
<tr><td>4d</td><td>296 kJ mol^{-1}</td><td>$$\begin{aligned}E = \frac{L \times h \times c}{\lambda} &= \frac{6.02\times10^{23}\ mol^{-1} \times 6.63\times10^{-34}\ J\ s \times 3\times10^{8}\ m\ s^{-1}}{405 \times 10^{-9} m}\\ &= 295848.9\ J\ mol^{-1}\\ &= 296\ kJ\ mol^{-1}\end{aligned}$$</td></tr>
<tr><td>5a</td><td>One answer from:<table><tr><td>blue</td><td>green</td><td>cyan</td></tr><tr><td>blue/green</td><td colspan="2">turquoise</td></tr></table></td><td>650nm is coloured red in visible spectrum so red wavelengths are absorbed by the complex and green / blue colours are transmitted.</td></tr>
<tr><td>5b</td><td>$1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{7}$</td><td>Cobalt atoms have electronic configuration: $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{7}4s^{2}$
Cobalt Co^{2+} ions have electronic configuration: $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{7}$ or [Ne] $3s^{2}$ $3p^{6}$ $3d^{7}$</td></tr>
</table>

<table>
<tr>
<td>5c</td>
<td>$[Co(Cl)_4]^{2-}$</td>
<td>

$$\underbrace{\text{Tetra}}_{\text{no. of ligands}}\underbrace{\text{chlorido}}_{\text{chloride ion ligand}}\underbrace{\text{cobalt}}_{\text{metal name}}\underbrace{\text{ate}}_{\text{negative complex}}\underbrace{\text{(II)}}_{\text{Charge on metal ion}} = [Co(Cl)_4]^{2-}$$

<table>
<tr><td>Neutral ligands include:</td><td>Negative Ligands include:</td><td>Central Ion:</td><td>Charge:</td></tr>
<tr>
<td>
<table>
<tr><td>Ligand</td><td>Name</td></tr>
<tr><td>H_2O</td><td>aqua</td></tr>
<tr><td>NH_3</td><td>ammine</td></tr>
<tr><td>CO</td><td>carbonyl</td></tr>
</table>
</td>
<td>
<table>
<tr><td>Ligand</td><td>Name</td></tr>
<tr><td>Chloride Cl^-</td><td>chlorido</td></tr>
<tr><td>Cyanide CN^-</td><td>cyanido</td></tr>
<tr><td>Nitrite NO_2^-</td><td>nitrito</td></tr>
</table>
</td>
<td><u>Positive Complex</u>:
metals keep their name
<u>Negative Complex</u>:
Metals end in ATE
e.g. Cuprate, Ferrate, Cobaltate</td>
<td>Charge of central ion is converted into roman numerals and in brackets</td>
</tr>
</table>
</td>
</tr>
<tr>
<td>6a</td>
<td>2.935</td>
<td>

$$\begin{aligned} pH &= \tfrac{1}{2}pK_a - \tfrac{1}{2}\log_{10} c \\ &= (\tfrac{1}{2} \times 4.87) - \tfrac{1}{2} \times \log_{10}(0.1) \\ &= 2.435 - (-0.5) \\ &= 2.935 \end{aligned}$$

</td>
</tr>
<tr>
<td>6b</td>
<td>6.17</td>
<td>

$$\text{concentration} = \frac{\text{no. of mol}}{\text{volume}} = \frac{0.20\text{ mol}}{0.1\text{ litres}} = 2\text{ mol l}^{-1}$$

$$\begin{aligned} pH = pK_a - \log\frac{[\text{acid}]}{[\text{salt}]} = 4.87 - \log\frac{0.10\text{ mol l}^{-1}}{2\text{ mol l}^{-1}} &= 4.87 - \log(0.05) \\ &= 4.87 - (-1.301) \\ &= 6.17 \end{aligned}$$

</td>
</tr>
<tr>
<td>7a</td>
<td>0.29V</td>
<td>
❶ $Cr^{3+} + 3e^- \rightarrow Cr$ $E^o = -0.74V$
❷ $Fe^{2+} + 2e^- \rightarrow Fe$ $E^o = -0.45V$

❶x-1 $Cr \rightarrow Cr^{3+} + 3e^-$ $E^o = +0.74V$
❷x1½ $1\tfrac{1}{2}Fe^{2+} + 3e^- \rightarrow 1\tfrac{1}{2}Fe$ $E^o = -0.45V$

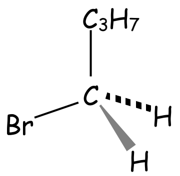
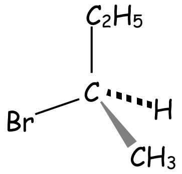
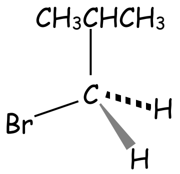
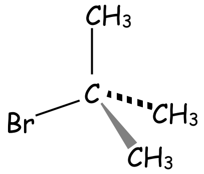
❶'+❷' + $Cr + 1\tfrac{1}{2}Fe^{2+} \rightarrow Cr^{3+} + 1\tfrac{1}{2}Fe$ $E^o = +0.29V$
</td>
</tr>
<tr>
<td>7b</td>
<td>-84.0 kJ mol^{-1}</td>
<td>
3mol of electrons transferred between half reactions ∴ n=3

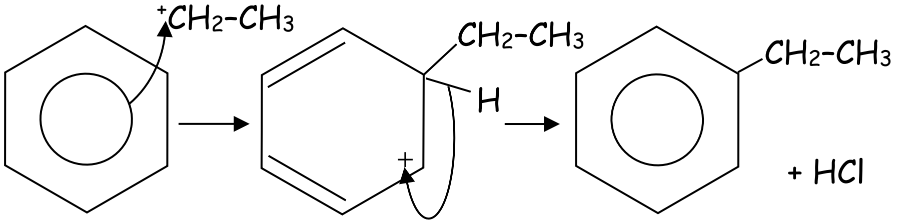
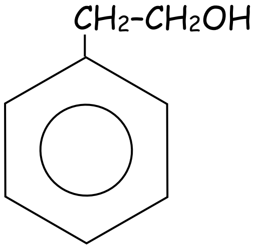
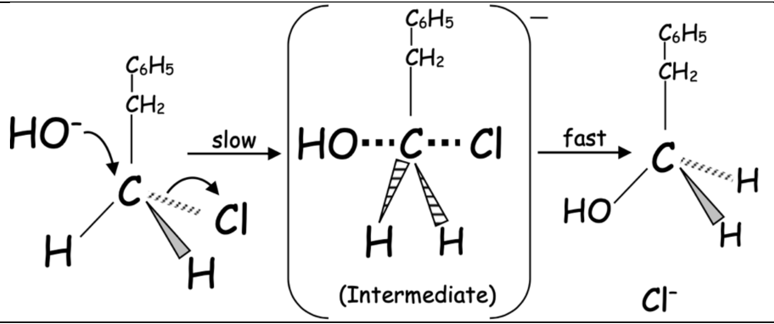
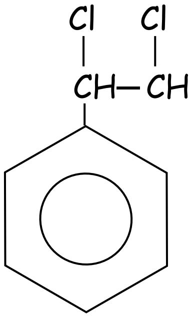
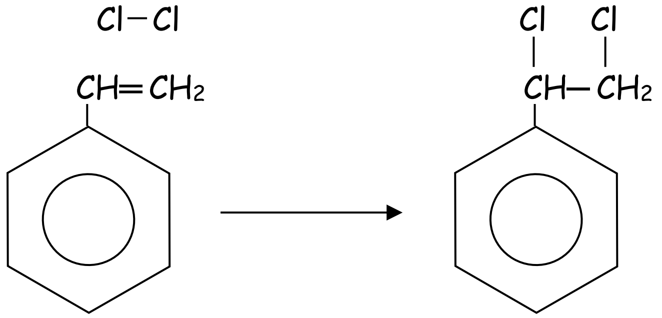
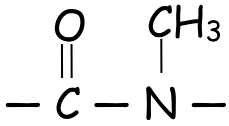
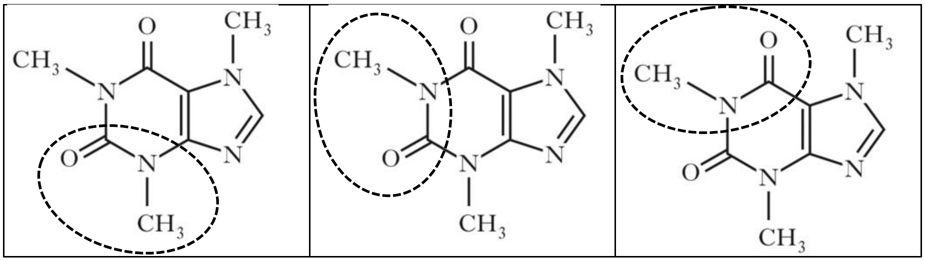
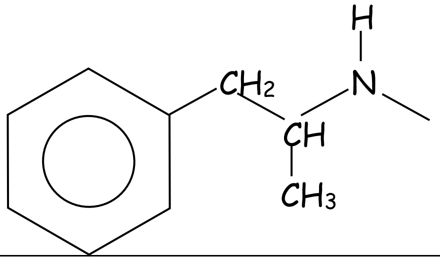
$$\begin{aligned} \Delta G^o &= -\ n \times F \times E^o \\ &= -\ 3 \times 96500\text{ C mol}^{-1} \times 0.29V \\ &= -\ 83955\text{ J mol}^{-1} \\ &= -\ 84.0\text{ kJ mol}^{-1} \end{aligned}$$

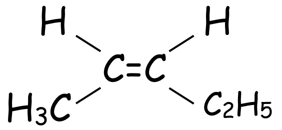
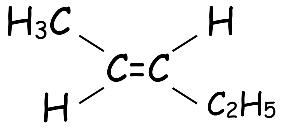
</td>
</tr>
<tr>
<td>7c</td>
<td>Answer to include:</td>
<td>
Aluminium as $\Sigma\Delta G^o$ is negative for: $^2/_3Cr_2O_3 \rightarrow {}^4/_3Cr + O_2$ and $^4/_3Al + O_2 \rightarrow {}^2/_3Al_2O_3$
or
Overall $\Sigma\Delta G^o$ is negative for (redox) reaction: $^2/_3Cr_2O_3 + {}^4/_3Al \rightarrow {}^4/_3Cr + {}^2/_3Al_2O_3$
</td>
</tr>
<tr>
<td>8a(i)</td>
<td>1 or 1st order</td>
<td>
<table>
<tr><td>$[C_4H_9Br]$/mol l^{-1}</td><td>[NaOH]/mol l^{-1}</td><td>Initial Rate/mol l^{-1} s^{-1}</td></tr>
<tr><td>8.0×10^{-4}</td><td>0.10</td><td>0.15</td></tr>
<tr><td>1.6×10^{-3}</td><td>0.10</td><td>0.30</td></tr>
</table>
Doubling $[C_4H_9Br]$ doubles the rate ∴ first order kinetics
</td>
</tr>
<tr>
<td>8a(ii)</td>
<td>Zero or no order</td>
<td>
<table>
<tr><td>$[C_4H_9Br]$/mol l^{-1}</td><td>[NaOH]/mol l^{-1}</td><td>Initial Rate/mol l^{-1} s^{-1}</td></tr>
<tr><td>1.6×10^{-3}</td><td>0.10</td><td>0.15</td></tr>
<tr><td>1.6×10^{-3}</td><td>0.20</td><td>0.30</td></tr>
</table>
Doubling [NaOH] does not change the rate ∴ zero order kinetics
</td>
</tr>
<tr>
<td>8b</td>
<td>$Rate=k[C_4H_9Br]$</td>
<td>$Rate = k[C_4H_9Br]^1[NaOH]^o = k[C_4H_9Br]$</td>
</tr>
<tr>
<td>8c</td>
<td>$187.5\ s^{-1}$</td>
<td>

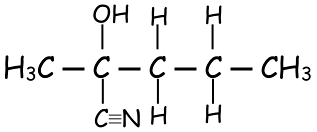
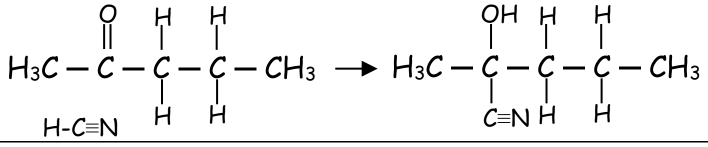
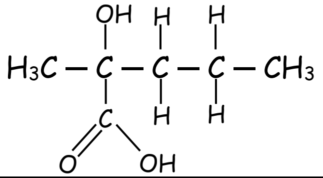
$$rate = k[C_4H_9Br] \therefore k = \frac{rate}{[C_4H_9Br]} = \frac{0.15\text{ mol l}^{-1}\text{ s}^{-1}}{8\times10^{-4}\text{ mol l}^{-1}} = 187.5\text{ s}^{-1}$$

</td>
</tr>
<tr>
<td>8d(i)</td>
<td>2-bromo-2-methylpropane
(2-bromomethylpropane)

Or tertiary structure</td>
<td rowspan="2">
<table>
<tr><td>1-bromobutane</td><td>2-bromobutane</td><td>1-bromo-2-methylpropane</td><td>2-bromo-2-methylpropane</td></tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr><td>primary halogenalkane</td><td>secondary halogenalkane</td><td>primary halogenalkane</td><td>tertiary halogenalkane</td></tr>
<tr>
<td colspan="3">Primary and secondary halogenalkanes react with NaOH by S_N2 mechanism. 2 particles are involved in the rate determining step where the nucleophilic species (OH^-ion) attacks the central carbon due to the lack of steric hindrance of primary/secondary structure.</td>
<td>Tertiary halogenalkanes react by S_N1 mechanism. Carbocations are formed first in the RDS and then the nucleophilic species (OH^-) attacks the planar carbocation intermediate to form alkanol</td>
</tr>
</table>
</td>
</tr>
<tr>
<td>8d(ii)</td>
<td>Tertiary halogenalkanes form more stable carbocation intermediates due to steric hindrance of the tertiary structure</td>
</tr>
</table>

9a	4	Each of the 4 Nitrogen atoms has a lone pair of electrons which are donated to the central metal ion to form a dative covalent bond.
9b	19.8%	1 mol $Ni(C_4H_7O_2N_2)_2$ = (1x58.7)+(8x12)+(14x1)+(4x16)+(4x14) = 58.7+96+14+64+56 = 288.7g $\text{Mass of Ni in red precipitate} = 0.942g \times \frac{\text{mass of Ni}}{\text{mass of complex}} = 0.942g \times \frac{58.7}{288.7} = 0.1915g$ $\%\text{Ni in impure salt} = \frac{0.1915}{0.968} \times 100 = 19.8\%$
10a	Electrophilic Substitution (or alkylation)	$Cl{-}CH_2CH_3 \xrightarrow[\text{(heterolytic fission)}]{\text{aluminium chloride } AlCl_3} {}^{+}CH_2CH_3 + Cl^-$ 
10b	Light or u.v. radiation	Light/uv radiation is required in the initiation step of a free radical chain reaction: $Cl_2 \longrightarrow 2Cl^{\bullet}$
10c		
10d	Elimination	KOH(aq) is used for nucleophilic substitution of –OH groups onto halogenalkanes KOH dissolved in ethanol is used for elimination reactions forming alkenes from halogenalkanes
10e		
11a	Any of the three: $-\overset{\overset{\displaystyle O}{\Vert}}{C}-\overset{\overset{\displaystyle CH_3}{\vert}}{N}-$	
11b	4-MTA	Primary amines have a nitrogen with 2 hydrogens and a carbon group attached to it e.g. $CH_3{-}NH_2$
11c	Diagram showing:	

<table>
<tr><td>12a</td><td>(conc) phosphoric acid
or orthophosphoric acid</td><td>PPA Technique Question</td></tr>
<tr><td>12b(i)</td><td>One answer from:</td><td><table><tr><td>It is denser than water</td><td>Layers separate better</td><td>Aqueous layer is more polar</td></tr><tr><td>Layers separate more quickly</td><td>Layers settle more quickly</td><td>To get a better separation</td></tr></table></td></tr>
<tr><td>12b(ii)</td><td>Separating Funnel</td><td>Other acceptable names: Separatory Funnel, Separation Funnel</td></tr>
<tr><td>12c</td><td>One answer from</td><td><table><tr><th>Chemical</th><th>Group Detected</th><th>Absorbance</th></tr><tr><td>Cyclohexene</td><td>C=C stretch</td><td>1620 to 1680 cm^{-1}</td></tr><tr><td>Cyclohexene</td><td>C-H stretch in C=C-H</td><td>3095 to 3010 cm^{-1}</td></tr><tr><td>Cyclohexanol</td><td>O-H stretch</td><td>3200 to 3650 cm^{-1}</td></tr></table></td></tr>
<tr><td>13a</td><td>
cis-pent-2-ene

trans-pent-2-ene</td><td>cis-geometric isomers have groups on same side of C=C double bond

trans-geometric isomers have groups on opposite sides of C=C double bond</td></tr>
<tr><td>13b</td><td>pentan-2-one</td><td>Acidified Permanganate (H^+/MnO_4^-) is an oxidising agent.
Compound A (pentan-2-ol) is a secondary alcohol and oxidises to become the ketone pentan-2-one.</td></tr>
<tr><td>13c(i)</td><td>Addition</td><td>H-CN is added across the C=O carbonyl group of pentan-2-one</td></tr>
<tr><td>13c(ii)</td><td>
$H_3C-\overset{OH}{\underset{C\equiv N}{C}}-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{H}{C}}-CH_3$</td><td></td></tr>
<tr><td>13d</td><td></td><td>Cyanohydrins hydrolyse in the presence of acid and the —C≡N groups become carboxyl —COOH groups</td></tr>
<tr><td>14a</td><td>$C_4H_{10}O$</td><td>Mass of carbon in CO_2 = $^{12}/_{44}$ x 11.89g = 3.243g
Mass of hydrogen in H_2O = $^{2}/_{18}$ x 6.08g = 0.676g
Mass of oxygen = 5g – (3.243+0.676) = 5 – 3.919 = 1.081g<table><tr><th>Elements</th><th>C</th><th>H</th><th>O</th></tr><tr><td>Mass or %</td><td>3.243g</td><td>0.676g</td><td>1.081g</td></tr><tr><td>Divide by RAM</td><td>$\frac{3.243g}{12g\ mol^{-1}}$
= 0.270mol</td><td>$\frac{0.676g}{1g\ mol^{-1}}$
= 0.676mol</td><td>$\frac{1.081g}{16g\ mol^{-1}}$
= 0.0676mol</td></tr><tr><td>Divide through by smallest number</td><td>$\frac{0.270mol}{0.0676mol}$
= 4</td><td>$\frac{0.676mol}{0.0676mol}$
= 10</td><td>$\frac{0.0676mol}{0.0676mol}$
1</td></tr><tr><td>Empirical Formula</td><td>4</td><td>10</td><td>1</td></tr></table></td></tr>
<tr><td>14b</td><td>C — O stretch</td><td>Alkyl ethers C—O bonds stretch at wavenumber range 1070-1150cm^{-1}</td></tr>
<tr><td>14c</td><td>$C_4H_{10}O$</td><td>$C_4H_{10}O$ = (4x12)+(10x1)+(1x16) = 48 + 10 + 16 = 74</td></tr>
<tr><td>14d</td><td>Ethoxyethane
Or
$C_2H_5OC_2H_5$</td><td>Possible $C_4H_{10}O$ ether structures:<table><tr><th colspan="3">Ethoxyethane</th><th colspan="3">methoxypropane</th></tr><tr><td colspan="3">$CH_3CH_2OCH_2CH_3$</td><td colspan="3">$CH_3OCH_2CH_2CH_3$</td></tr><tr><td>Chemical Shift</td><td>Group</td><td>Relative Intensity</td><td>Chemical Shift</td><td>Group</td><td>Relative Intensity</td></tr><tr><td>0.9-1.5</td><td>$-CH_3$</td><td>3</td><td>0.9-1.5</td><td>$-CH_3$</td><td>3</td></tr><tr><td>3.5-3.9</td><td>$R-CH_2-O-$</td><td>2</td><td>3.5-3.9</td><td>$R-CH_2-O-$</td><td>2</td></tr><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr></table></td></tr>
</table>