Markscheme

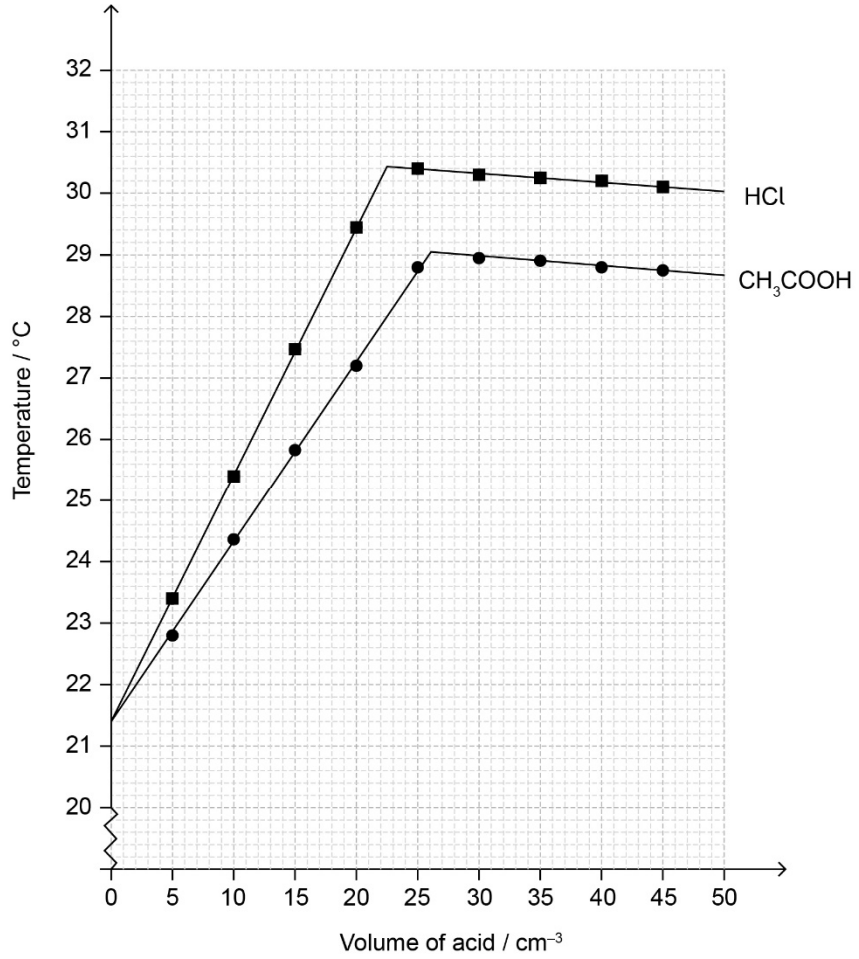
November 2017

Chemistry

Higher level

Paper 2

19 pages

Question			Answers	Notes	Total
1.	a		 21.4 °C ✓	*Accept values in the range of 21.2 to 21.6* °C. *Accept two different values for the two solutions from within range.*	**1**

Question			Answers	Notes	Total
1.	b		*HCl:* 30.4 «°C» ✓ *CH_3COOH:* 29.0 «°C» ✓	*Accept range 30.2 to 30.6* °C. *Accept range 28.8 to 29.2* °C.	**2**
1.	c		***ALTERNATIVE 1*** «volume CH_3COOH =» 26.0 «cm^3» ✓ «$[CH_3COOH] = 0.995 \text{ mol dm}^{-3} \times \frac{50.0 \text{ cm}^3}{26.0 \text{ cm}^3}$ =» 1.91 «mol dm^{-3}» ✓ ***ALTERNATIVE 2*** «n(NaOH) = 0.995 mol $dm^{-3} \times 0.0500$ dm^3 =» 0.04975 «mol» ✓ «$[CH_3COOH] = \frac{0.04975}{0.0260} \text{ dm}^3$ =» 1.91 «mol dm^{-3}» ✓	*Accept values of volume in range 25.5 to 26.5 cm^3.* *Award **[2]** for correct final answer.*	**2**
1.	d	i	«total volume = 50.0 + 26.0 =» 76.0 cm^3 ***AND*** «temperature change 29.0 − 21.4 =» 7.6 «°C» ✓ «q = 0.0760 kg × 4.18 kJ kg^{-1} K^{-1} × 7.6 K =» 2.4 «kJ» ✓	*Award **[2]** for correct final answer.*	**2**

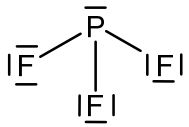
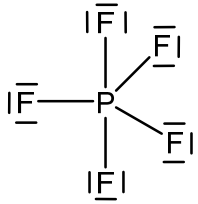
Question			Answers	Notes	Total
1.	d	ii	«n(NaOH) = 0.995 mol dm^{-3} × 0.0500 dm^3 =» 0.04975 «mol» ***OR*** «n(CH_3COOH) = 1.91 mol dm^{-3} × 0.0260 dm^3 =» 0.04966 «mol» ✓ « $\Delta H = -\frac{2.4\,kJ}{0.04975\,mol}$ =» −48 / −49 «kJ mol^{-1}» ✓	*Award **[2]** for correct final answer.* *Negative sign is required for M2.*	**2**
1.	e		CH_3COOH is weak acid/partially ionised ✓ energy used to ionize weak acid «before reaction with NaOH can occur» ✓		**2**
1.	f	i	«initially steep because» greatest concentration/number of particles at start ***OR*** «slope decreases because» concentration/number of particles decreases ✓ volume produced per unit time depends on frequency of collisions ***OR*** rate depends on frequency of collisions ✓		**2**
1.	f	ii	mass/amount/concentration of metal carbonate more in X ***OR*** concentration/amount of CH_3COOH more in X ✓		**1**

Question			Answers	Notes	Total
2.	a		«series of» lines ***OR*** only certain frequencies/wavelengths ✓ convergence at high«er» frequency/energy/short«er» wavelength ✓	*M1 and/or M2 may be shown on a diagram.*	**2**
2.	b		electron transfer/transition between high«er» energy level to low«er» energy level ***OR*** electron transitions into first energy level causes UV series ***OR*** transition into second energy level causes visible series ***OR*** transition into third energy level causes infrared series ✓	*Accept any of the points shown on a diagram.*	**1**
2.	c		$24 \times 0.786 + 25 \times 0.101 + 26 \times 0.113$ ✓ 24.33 ✓	*Award **[2]** for correct final answer.* *Award **[0]** for 24.31 with no working (data booklet value).*	**2**
2.	d	i	carbon: «$\frac{0.4490\,\text{g}}{44.01\,\text{g mol}^{-1}}$=» 0.01020 «mol» / 0.1225 «g» ***OR*** hydrogen: «$\frac{0.1840\,\text{g} \times 2}{18.02\,\text{g mol}^{-1}}$=» 0.02042 «mol» / 0.0206 «g» ✓ oxygen: «0.1595 − (0.1225 + 0.0206) =» 0.0164 «g» / 0.001025 «mol» ✓ empirical formula: $C_{10}H_{20}O$ ✓	*Award **[3]** for correct final answer.* *Do **not** award M3 for a hydrocarbon.*	**3**

Question			Answers	Notes	Total
2.	d	ii	«temperature =» 423 K ***OR*** $M = \frac{mRT}{pV}$ ✓ «$M = \frac{0.150\,\text{g} \times 8.31\,\text{JK}^{-1}\,\text{mol}^{-1} \times 423\,\text{K}}{100.2\,\text{kPa} \times 0.0337\,\text{dm}^3}$ =» 156 «g mol^{-1}» ✓	*Award **[1]** for correct answer with no working shown.* *Accept "pV = nRT **AND** n = $\frac{m}{M}$" for M1.*	**2**
2.	d	iii	$C_{10}H_{20}O$ ✓		**1**
2.	e	i	Cl_2: first ✓ *NO*: second ✓		**2**
2.	e	ii	rate = $k\,[NO]^2\,[Cl_2]$ ✓		**1**
2.	e	iii	180 / 1.80 × 10^2 «$\text{dm}^6\,\text{mol}^{-2}\,\text{min}^{-1}$» ✓		**1**

Question			Answers	Notes	Total
3.	**a**		increasing number of protons ***OR*** increasing nuclear charge ✓ «atomic» radius/size decreases ***OR*** same number of shells ***OR*** similar shielding «by inner electrons» ✓ **«**greater energy needed to overcome increased attraction between nucleus and electrons**»**		**2**
3.	**b**		*Any three of:* *Group 1:* atomic/ionic radius increases ✓ smaller charge density ***OR*** force of attraction between metal ions and delocalised electrons decreases ✓ *Group 17:* number of electrons/surface area/molar mass increase ✓ London/dispersion/van der Waals'/vdw forces increase ✓	*Do **not** accept discussion of attraction between valence electrons and nucleus for M2.* *Accept "weaker metallic bonds" for M2.* *Accept "atomic mass" for "molar mass".*	**3 max**

Question			Answers	Notes	Total
3.	**c**		P_4O_{10} (s) + $6H_2O$ (l) → $4H_3PO_4$ (aq) ✓	*Accept "P_4O_{10} (s) + $2H_2O$ (l) → $4HPO_3$(aq)" (initial reaction).*	**1**
3.	**d**	**i**	**«**distorted**»** octahedral ✓	*Accept "square bipyramid".*	**1**
3.	**d**	**ii**	*Charge on complex ion:* 1+/+ ✓ *Oxidation state of cobalt:* +2 ✓		**2**
3.	**e**		Lewis **«**acid-base reaction**»** ✓ H_2O: electron/e^- pair donor ***OR*** Co^{2+}: electron/e^- pair acceptor ✓		**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>4.</td><td>a</td><td></td><td>
<table>
<tr><td></td><td>PF_3</td><td>PF_5</td></tr>
<tr><td>Lewis structure</td><td>  ✓</td><td>  ✓</td></tr>
<tr><td>Molecular geometry</td><td>trigonal pyramidal ✓</td><td>trigonal bipyramidal ✓</td></tr>
<tr><td>Bond angles</td><td>≤109«°» ✓</td><td>90«°» AND 120«°», «180«°» » ✓</td></tr>
</table>
</td><td>Accept any combination of dots, crosses and lines.
Penalize missing lone pairs once only.
Do not apply ECF for molecular geometry.
Accept values in the range 95–109 for PF_3.</td><td>6</td></tr>
<tr><td>4.</td><td>b</td><td></td><td>PF_3 polar AND PF_5 non-polar ✓</td><td>Apply ECF from part (a) molecular geometry.</td><td>1</td></tr>
<tr><td>4.</td><td>c</td><td></td><td>sp^3 ✓</td><td></td><td>1</td></tr>
</table>

Question			Answers	Notes	Total
5.	**a**		$\Delta H^{\ominus}$= [–165.2 + 2(–296.9) + 2(–92.3)] – [–454.7 + 2(–245.7)] ✓ **«**$\Delta H^{\ominus}$=+**»**2.5 **«**kJ**»** ✓	*Award **[2]** for correct final answer.* *Award **[1]** for –2.5 «kJ».* *Do **not** accept ECF for M2 if more than one error in M1.*	**2**
5.	**b**		**«**$\Delta S^{\ominus}$= [208.5 + 2(248.1) + 2(186.8)] – [166.9 + 2(278.6)] **»** **«**$\Delta S^{\ominus}$= +**»** 354.2 **«**J K^{-1} mol^{-1}**»** ✓		**1**
5.	**c**		**«**3 moles of**»** liquid to **«**4 moles of**»** gas ***OR*** **«**large**»** positive ΔS ***OR*** **«**large**»** increase in entropy ✓ $T\Delta S > \Delta H$ **«**at the reaction temperature**»** ✓		**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>6.</td><td>a</td><td>i</td><td>$K_c = \frac{[HI]^2}{[H_2][I_2]}$ ✓</td><td></td><td>1</td></tr>
<tr><td>6.</td><td>a</td><td>ii</td><td>45.6 ✓</td><td></td><td>1</td></tr>
<tr><td>6.</td><td>a</td><td>iii</td><td>$\Delta G^{\ominus}$ = «– $RT \ln K$ = – (0.00831 kJ K^{-1} mol^{-1} × 761 K × ln 45.6) =» – 24.2 «kJ» ✓</td><td></td><td>1</td></tr>
<tr><td>6.</td><td>a</td><td>iv</td><td>
<table>
<tr><th></th><th>Effect</th><th></th><th>Reason</th></tr>
<tr><td>Increasing the volume, at constant temperature</td><td>none/no effect</td><td>AND</td><td>same number of «gas» moles/molecules on both sides ✓</td></tr>
<tr><td>Increasing the temperature, at constant pressure</td><td>moves to left</td><td>AND</td><td>«forward» reaction is exothermic ✓</td></tr>
</table>
</td><td>Award [1 max] if both effects are correct.
Reason for increasing volume:
Accept “concentration of all reagents reduced by an equal amount so cancels out in K_c expression”.
Accept “affects both forward and backward rates equally.”</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
6.	b	i	HCO_3^- ***AND*** H_2O ✓		1
6.	b	ii	species that has one less proton/H^+ ion **«**than its conjugate acid**»** ***OR*** species that forms its conjugate acid by accepting a proton ***OR*** species that is formed when an acid donates a proton ✓	*Do **not** accept "differs by one proton/H^+ from conjugate acid".*	1
6.	b	iii	oxide ion/O^{2-} ✓		1
6.	c	i	$[H_3O^+] = 6.76 \times 10^{-5}$ **«**mol dm^{-3}**»** ✓ $K_a = \frac{\left(6.76 \times 10^{-5}\right)^2}{\left(0.010 - 6.76 \times 10^{-5}\right)} / \frac{\left(6.76 \times 10^{-5}\right)^2}{0.010}$ ✓ 4.6×10^{-7} ✓	*Accept 4.57×10^{-7}.* *Award **[3]** for correct final answer.*	3
6.	c	ii	**«**$\frac{1.00 \times 10^{-14}}{4.6 \times 10^{-7}}$**=»** 2.17×10^{-8} ***OR*** **«**$\frac{1.00 \times 10^{-14}}{4.57 \times 10^{-7}}$**=»** 2.19×10^{-8} ✓		1

Question			Answers	Notes	Total
6.	d		insufficient data to make generalization ***OR*** need to consider **«**much**»** larger number of acids ***OR*** hypothesis will continue to be tested with new acids to see if it can stand the test of time ✓ **«**hypothesis is false as**»** other acids/HCl/HBr/HCN/transition metal ion/BF_3 do not contain oxygen ***OR*** other acids/HCl/HBr/HCN/transition metal ion/BF_3 falsify hypothesis ✓ correct inductive reasoning **«**based on the limited sample**»** ✓ **«**hypothesis not valid**»** as it contradicts current/accepted theories/Brønsted-Lowry/Lewis theory ✓		**2 max**

Question			Answers	Notes	Total
7.	a		$Ni(s) + I_2(aq) \rightarrow 2I^-(aq) + Ni^{2+}(aq)$ ✓		1
7.	b		electron movement **«**in the wire**»** from Mn(s) to Ni(s) ✓ $E^{\ominus}$ **«**for reduction**»** of Ni^{2+} is greater/less negative than $E^{\ominus}$ **«**for reduction**»** of Mn^{2+} ***OR*** Ni^{2+} is stronger oxidizing agent than Mn^{2+} ***OR*** Mn is stronger reducing agent than Ni ✓		2
7.	c		**«**0.54 V – (–1.18 V) = +**»**1.72 **«**V**»** ✓	*Do **not** accept –1.72 V.*	1
7.	d		Mn **«**(s)**»** ✓		1

Question			Answers	Notes	Total
7.	e		*Positive electrode (anode):* $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ ✓ Cl^- oxidized because higher concentration ***OR*** electrode potential/*E* depends on concentration ***OR*** electrode potential values «of H_2O and Cl^-» are close ✓ *Negative electrode (cathode):* $2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$ ***OR*** $2H^+(aq) + 2e^- \rightarrow H_2(g)$ ✓ H_2O/H^+ reduced because Na^+ is a weaker oxidizing agent ***OR*** Na^+ not reduced to Na in water ***OR*** H^+ easier to reduce than Na^+ ***OR*** H lower in activity series «than Na» ✓	*Accept* ⇌.	**4**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>8.</td><td>a</td><td>i</td><td>oxidation/redox AND acidified «potassium» dichromate(VI)
OR
oxidation/redox AND «acidified potassium» manganate(VII) ✓</td><td>Accept “acidified «potassium» dichromate” OR “«acidified potassium» permanganate”.
Accept name or formula of the reagent(s).</td><td>1</td></tr>
<tr><td>8.</td><td>a</td><td>ii</td><td>ALTERNATIVE 1 using $K_2Cr_2O_7$:
Compound A: orange to green AND secondary hydroxyl
OR
Compound A: orange to green AND hydroxyl oxidized «by chromium(VI) ions» ✓

Compound B: no change AND tertiary hydroxyl «not oxidized by chromium(VI) ions» ✓

ALTERNATIVE 2 using $KMnO_4$:
Compound A: purple to colourless AND secondary hydroxyl
OR
Compound A: purple to colourless AND hydroxyl oxidized «by manganese(VII) ions» ✓

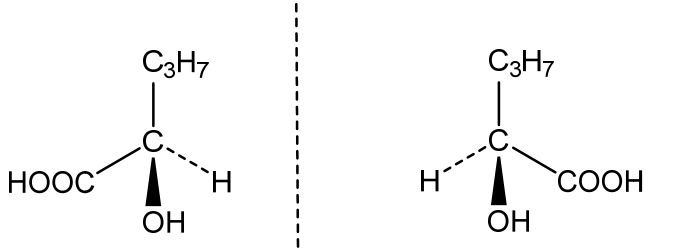
Compound B: no change AND tertiary hydroxyl «not oxidized by manganese(VII) ions» ✓</td><td>Award [1] for “A: orange to green AND B: no change”.
Award [1] for “A: secondary hydroxyl AND B: tertiary hydroxyl”.

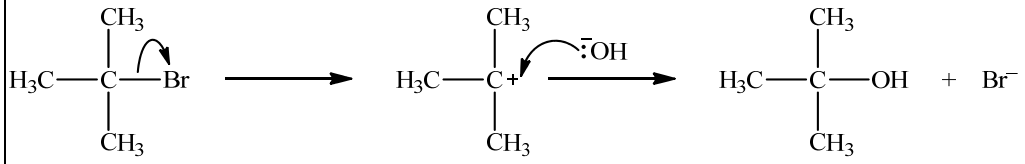
Accept “alcohol” for “hydroxyl”.

Award [1] for “A: purple to colourless AND B: no change”
Award [1] for “A: secondary hydroxyl AND B: tertiary hydroxyl”.
Accept “purple to brown” for A.</td><td>2</td></tr>
<tr><td>8.</td><td>a</td><td>iii</td><td><table><tr><th>Compound</th><th>Number of signals</th><th>Ratio of areas</th></tr><tr><td>A</td><td>5 ✓</td><td>6:1:1:1:1 ✓</td></tr><tr><td>B</td><td>4 ✓</td><td>6:1:1:2 ✓</td></tr></table></td><td>Accept ratio of areas in any order.
Do not apply ECF for ratios.</td><td>4</td></tr>
</table>

(continued…)

(Question 8a continued)

Question			Answers	Notes	Total
8.	**a**	**iv**	A ***AND*** it has a chiral centre/asymmetric carbon atom/carbon with 4 different substituents ✓		**1**
8.	**a**	**v**	 ✓	*Accept structures without tapered bonds.*	**1**
8.	**b**		*Initiation:* $Br_2 \xrightarrow{UV\ /hv/heat} 2Br\bullet$ ✓ *Propagation:* $Br\bullet + C_2H_6 \rightarrow C_2H_5\bullet + HBr$ ✓ $C_2H_5\bullet + Br_2 \rightarrow C_2H_5Br + Br\bullet$ ✓ *Termination:* $Br\bullet + Br\bullet \rightarrow Br_2$ ***OR*** $C_2H_5\bullet + Br\bullet \rightarrow C_2H_5Br$ ***OR*** $C_2H_5\bullet + C_2H_5\bullet \rightarrow C_4H_{10}$ ✓	*Reference to UV/hv/heat not required.* *Accept representation of radical without • (eg, Br, C_2H_5) if consistent throughout mechanism.* *Accept further bromination.* *Award **[3 max]** if initiation, propagation and termination are not stated or are incorrectly labelled for equations.* *Award **[3 max]** if methane is used instead of ethane, and/or chlorine is used instead of bromine.*	**4**
8.	**c**		concentrated HNO_3 ***AND*** concentrated H_2SO_4 ✓	*"concentrated" must occur at least once (with either acid).*	**1**

Question			Answers	Notes	Total
8.	d		$HNO_3 + 2H_2SO_4 \rightleftharpoons H_3O^+ + NO_2^+ + 2HSO_4^-$ ✓	*Accept:* $HNO_3 + H_2SO_4 \rightleftharpoons NO_2^+ + HSO_4^- + H_2O$ *Accept:* $HNO_3 + H_2SO_4 \rightleftharpoons H_2NO_3^+ + HSO_4^-$. *Accept single arrow instead of equilibrium sign.* *Accept equivalent two step reactions in which sulfuric acid first behaves as strong acid and protonates nitric acid, before behaving as dehydrating agent removing water from it.*	**1**
8.	e		 curly arrow showing Br^- leaving ✓ representation of tertiary carbocation ✓ curly arrow going from lone pair/negative charge on O in ^-OH to C^+ ✓ formation of $(CH_3)_3COH$ ***AND*** Br^- ✓	*Do **not** accept curly arrow originating from C of C–Br bond.* *Do **not** accept arrow originating on H in ^-OH.* *Accept Br^- anywhere on product side in the reaction scheme.* *Award **[2 max]** for an S_N2 type mechanism.*	**4**