Y6 PRELIMINARY EXAMINATION 2022
CHEMISTRY HIGHER LEVEL
PAPER 1 MARKSCHEME

1.	C	16.	B	31.	D	46.	–
2.	B	17.	A	32.	A	47.	–
3.	A	18.	D	33.	A	48.	–
4.	C	19.	A	34.	C	49.	–
5.	D	20.	C	35.	C	50.	–
6.	A	21.	B	36.	D	51.	–
7.	D	22.	B	37.	B	52.	–
8.	A	23.	C	38.	D	53.	–
9.	D	24.	B	39.	D	54.	–
10.	B	25.	A	40.	D	55.	–
11.	D	26.	D	41.	–	56.	–
12.	B	27.	D	42.	–	57.	–
13.	D	28.	C	43.	–	58.	–
14.	A	29.	A	44.	–	59.	–
15.	C	30.	B	45.	–	60.	–

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PAPER 2 MARKSCHEME

Discretionary QC penalty: -1 M for illegible handwriting, writing outside of the box, using correction tape/fluid and/or using non-blue or non-black ink pen.

Question			Answers	Notes	Total
1.	a		«$\frac{8.802\text{ g}}{44.01\text{ g mol}^{-1}}$ =» 0.2000 «mol of C/CO_2» *AND* «$\frac{3.604\text{ g}}{18.02\text{ g mol}^{-1}}$ =» 0.2000 «mol of H_2O» / 0.4000 «mol of H» *OR* «$\frac{8.802\text{ g}}{44.01\text{ g mol}^{-1}}$ ×12.01 g mol^{-1} =» 2.402 «g of C» *OR* «$\frac{3.604\text{ g}}{18.02\text{ g mol}^{-1}}$ ×2×1.01 g mol^{-1} =» 0.404 «g of H» ✓ «4.406 g – 2.806 g» = 1.600 «g of O» ✓ «$\frac{2.402\text{ g}}{12.01\text{ g mol}^{-1}}$ = 0.2000 mol C; $\frac{0.404\text{ g}}{1.01\text{ g mol}^{-1}}$ = 0.400 mol H; $\frac{1.600\text{ g}}{16.00\text{ g mol}^{-1}}$ = 0.1000 mol O» C_2H_4O ✓	*Award [3] for correct final answer.*	3

Question			Answers	Notes	Total
1.	b		«$\frac{88.12\text{ g mol}^{-1}}{44.06\text{ g mol}^{-1}}$ = 2» $C_4H_8O_2$ ✓	C_2S_2 *if CS is used* *reasonable ecf*	1
1.	c		See table below	*Award [1 max] for correctly identifying all 3 compounds without valid reasons given.* *Accept specific values of wavenumbers within each range*	3

Spectrum	Identity	Reason
A	Propan-1-ol	absence of carbonyl/C=O «absorption»/ no peak in 1700 - 1750 «cm^{-1}» range ***OR*** presence of hydroxyl/O-H in alcohols «absorption»/peak in 3200 – 3600 «cm^{-1}» range ✓
B	Propanoic acid	**ALTERNATIVE 1:** carbonyl/C=O ***AND*** hydroxyl/O-H «in carboxylic acids absorptions» ***OR*** «strong» peaks in 2500 – 3000 «cm^{-1}» ***AND*** 1700 – 1750 «cm^{-1}» ranges ✓ **ALTERNATIVE 2:** O-H in carboxylic acids «absorption» ***AND*** 2500 – 3000 «cm^{-1}» range ✓ **ALTERNATIVE 3:** strong/broad «peak» ***AND*** 2500 – 3000 «cm^{-1}» range ✓
C	Propanal	presence of carbonyl/C=O «absorption»/ peak in 1700 – 1750 «cm^{-1}» range ***AND*** absence of hydroxyl/O-H «in carboxylic acids absorption»/ no «broad» peak in 2500 – 3000 «cm^{-1}» range ✓

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>1</td><td>d</td><td></td><td>
<table>
<tr><th>Compound</th><th>Number of signals</th><th>Splitting pattern of $-CH_3$</th></tr>
<tr><td>propanone</td><td>1</td><td>singlet</td></tr>
<tr><td>propanal</td><td>3</td><td>triplet</td></tr>
</table>
</td><td>Accept 1 and 3 for splitting pattern

Accept 1:2:1 for triplet</td><td>2</td></tr>
<tr><td>1.</td><td>e</td><td></td><td>CH_3O^+ OR CH_2OH^+</td><td>Do not accept answer without positive charge</td><td>1</td></tr>
<tr><td>1.</td><td>f</td><td></td><td>$K_2Cr_2O_7/Cr_2O_7^{2-}$/«potassium» dichromate «(VI)» AND acidified/H^+
OR
«acidified potassium» manganate(VII) / «H^+ and» $KMnO_4$ / «H^+ and» MnO_4^- ✓</td><td>Accept "H_2SO_4" or "H_3PO_4" for "H^+". Do not accept HCl.

Accept "permanganate" for "manganate(VII)".</td><td>1

1</td></tr>
<tr><td colspan="5">Total</td><td>11</td></tr>
</table>

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>2.</td><td>a</td><td></td><td>Mobile/delocalized <<sea of >> electrons ✓</td><td></td><td>1</td></tr>
<tr><td>2.</td><td>b</td><td></td><td> 
two regions of small increases AND a large increase between them ✓

large increase from 6th to 7th ✓</td><td>Accept line/curve showing these trends</td><td>2</td></tr>
<tr><td>2.</td><td>c</td><td></td><td>nuclear charge/number of protons/Z/Zeff increases «causing a stronger pull on the outer electrons» ✓

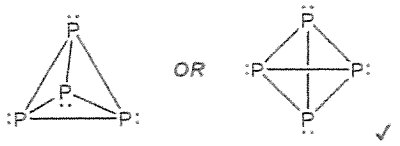
same number of shells/«outer» energy level/shielding ✓</td><td></td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
	d		P has «three» unpaired electrons in 3p sub-level ***AND*** S has one full 3p orbital «and two 3p orbitals with unpaired electrons» ***OR*** P: $[Ne]3s^2 3p_x^1 3p_y^1 3p_z^1$ ***AND*** S: $[Ne]3s^2 3p_x^2 3p_y^1 3p_z^1$ ✓ repulsion between paired electrons in sulfur «and therefore easier to remove» ✓	*Accept orbital diagrams for 3p sub-level for M1. Ignore other orbitals or sub-levels.* *Accept "removing electron from S gives more stable half-filled sub-level" for M2.*	2
2.	e		Any two of : Forms acidic oxides <<rather than basic oxides>> ✓ Forms covalent/bonds compounds <<with other non-metals>> ✓ Forms anions <<rather than cations>> ✓ Behave as an oxidizing agent <<rather than a reducing agent>> ✓	*Award [1 max]* for 2 correct non-chemical properties such as : non-conductor, high ionization energy, high electronegativity, low electron affinity. Accept "does not react with ACID to form H_2"	2
2.	f	i	electrostatic attraction ✓ between oppositely charged ions/between Fe^{2+} and S^{2-} ✓		2
2.	f	ii	allows them to explain/predict the properties of different compounds/substances / inferred/deduced ***OR*** enables them to generalise about substances	*Accept other valid answers.*	1

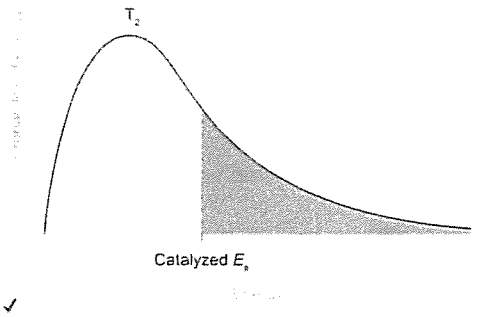
Question			Answers	Notes	Total
			OR enables them to make predictions ✓		
2	g	i	$4FeS(s) + 7O_2(g) \rightarrow 2Fe_2O_3(s) + 4SO_2(g)$ ✓	*Accept any correct ratio*	1
2	g	ii	−2 to +4 ✓	*Accept +6* Do not accept 2- to 4+.	1
2	g	iii	sulfur dioxide/SO_2 causes acid rain ✓	*Accept sulfur dioxide/SO_2/dust causes respiratory problems* *Do not accept just "causes respiratory problems" or "causes acid rain".*	1
				Total	15

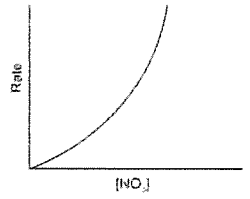
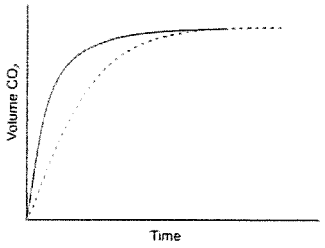
Question			Answers	Notes	Total
3.	a		1: 2 ✓		1
3	b		Fe^{3+} : $[Ar]3d^5$ ✓	*Accept "$[Ar]\ 3d^5 4s^0$".* *Do not award mark for full electron configurations "$1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$".*	1
3.	c		<table><tr><th></th><th>*Protons*</th><th></th><th>*Neutrons*</th><th></th><th>*Electrons*</th><th></th></tr><tr><td></td><td>26</td><td rowspan="2">***AND***</td><td>28</td><td rowspan="2">***AND***</td><td>26</td><td>✓</td></tr><tr><td></td><td>26</td><td>30</td><td>23</td><td>✓</td></tr></table>	*Award **[1 max]** for 4 correct values.*	2
3.	d		Ligands donate pairs of electrons to metal ions ***OR*** Forms coordinate/dative bond ✓ Ligands are Lewis bases **AND** metal <<ions>> are Lewis acids ✓	*Reject covalent bond*	2
3	e		$[Fe(CN)_6]^{3-}$ ***AND*** CN^- /ligand causes larger splitting «in d-orbitals compared to H_2O» ✓ ***OR*** $[Fe(CN)_6]^{3-}$ ***AND*** CN^- ligand associated with a higher Δ «crystal field» splitting energy/energy difference «in the spectrochemical series compared to H_2O » ✓	*Accept "$[Fe(CN)_6]^{3-}$ **AND** «CN^-» strong field ligand".*	1

Question			Answers	Notes	Total
3.	f		any value or range between 647 and 700 nm ✓		1
3.	g		Zn^{2+} has a full d-shell ***OR*** does not form « ions with» an incomplete d-shell ✓ Unable to undergo d→d transition **OR** Electron from the lower d orbitals unable to get excited to higher d orbitals as they are fully occupied (OWTTE) ✓	*Accept ZINC has full d-shell* *Reject if mention "no d-orbital splitting".*	2
				Total	10

Question			Answers	Notes	Total
4.	a		 OR ✓		1
4.	b		Electron domain geometry: tetrahedral ✓ Molecular geometry: trigonal pyramidal ✓ Bond angle: 100° ✓	*Accept any value or range within the range 91-108«°» for M3.* Accept less than 109.5^0	3
4.	c	i	«$-398.9\ kJ\ mol^{-1} - (-306.4\ kJ\ mol^{-1})$ =» -92.5 «$kJ\ mol^{-1}$» ✓		1
4.		ii	«$\Delta S = 364.5\ J\ K^{-1}\ mol^{-1} - (311.7\ J\ K^{-1}\ mol^{-1} + 223.0\ J\ K^{-1}\ mol^{-1})$ =» -170.2 «$J\ K^{-1}\ mol^{-1}$» ✓		1
4.		iii	«ΔS =» -0.1702 «$kJ\ mol^{-1}\ K^{-1}$» *OR* 298 «K» ✓ «$\Delta G = -92.5\ kJ\ mol^{-1} - (298\ K \times -0.1702\ kJ\ mol^{-1}\ K^{-1})$ =» -41.8 «$kJ\ mol^{-1}$» ✓	*Award [2] for correct final answer. If -87.6 and -150.5 are used then -42.8.* *Allow ecf*	2

Question			Answers	Notes	Total
4.		iv	«$\Delta G = -41.8\ kJ\ mol^{-1} = -\frac{8.31\ J\ mol^{-1}\ K^{-1}}{1000} \times 298\ K \times \ln K$» *OR* «$\Delta G = -41800\ J\ mol^{-1} = -8.31\ J\ mol^{-1}K^{-1} \times 298\ K \times \ln K$» «$\ln K$ = =» 16.9 ✓ «$K = e^{16.9}$ =» 2.19×10^7 ✓	*Award [2] for correct final answer.* *Accept range of $1.80 \times 10^6 - 2.60 \times 10^7$. If -43.5 is used then 4.25×10^7.*	2
4.		v	«K_c =» $\frac{[PCl_5]}{[PCl_3]\,[Cl_2]}$ ✓		1
4.		vi	«shifts» left/towards reactants *AND* «forward reaction is» exothermic/ΔH is negative ✓	*Allow ecf from (i)*	1
				Total	12

Question			Answers	Notes	Total
5.	a	i	B: reactant D: intermediate		2
5.	a	ii	Rate = k[A][B]		1
5.	a	ii	1.80 <<mol dm^{-3} s^{-1}>>		1
5.	b	i	 ✓ curve higher ***AND*** to left of T_1 ✓ new/catalysed E_a marked ***AND*** to the left of E_a of curve T_1	*Do **not** penalize curve missing a label, not passing exactly through the origin, or crossing x-axis after Ea.* *Do **not** award M1 if curve drawn shows significantly more/less molecules/greater/smaller area under curve than curve 1.* *Accept E_a drawn to T_1 instead of curve drawn as long as to left of marked E_a.*	2

5.	b	ii	 ✓	*Curve must go through origin.*	1
5.	b	iii	 curve starting from origin with steeper gradient ***AND*** reaching same maximum volume 1 ✓		1
				Total	8

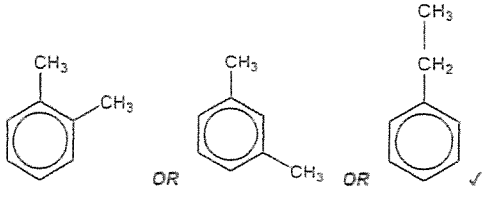
Question			Answers	Notes	Total
6.	a		Q: non-equilibrium concentration **AND** K_c : equilibrium concentrations *OR* Q: <<measured>> at any time **AND** K_c : <<measured>>> at equilibrium ✓		1
6.	b		«$Q = \frac{[SO_3]^2}{[SO_2]^2[O_2]} = \frac{1.00^2}{1.00^2 \times 2.00}$ » = 0.500 ✓ Reverse reaction favoured/ reaction proceeds to the left **AND** $Q > K_c$ / 0.500 > 0282 ✓	*Do not award M2 without M1*	2
				Total	3

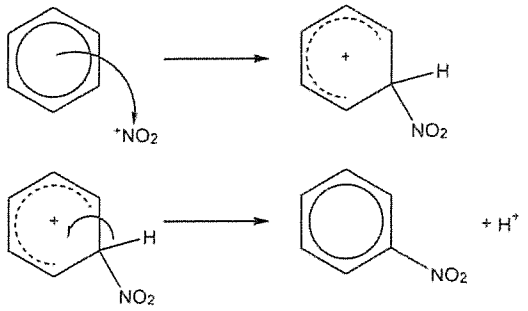
Question			Answers	Notes	Total
7.	a	i	B: CH_3COOH *AND* CH_3COO^- ✓ C: CH_3COO^- ✓	*(N20/P2/TZ0)* *Accept names.* *Accept CH_3COOK for CH_3COO^-*	2
7.	a	ii	phenolphthalein ✓	*Accept "phenol red" or "bromothymol blue".*	1
7.	a	iii	B *AND* the region where small additions «of the base/KOH » result in little or no change in pH *OR* B *AND* the flattest region of the curve «at intermediate pH/before equivalence point » *OR* B *AND* half the volume needed to reach equivalence point *OR* B *AND* similar amounts of weak acid/CH_3COOH/ethanoic acid *AND* conjugate base/CH_3COO^-/ethanoate ✓		1

7.	a	iv	<<When small amount of strong alkali is added>> : $CH_3COOH\ (aq) + OH^-\ (aq) \rightarrow CH_3COO^-\ (aq) + H_2O\ (l)$ ✓ **OR** $CH_3COOH\ (aq) \rightleftharpoons H^+\ (aq) + CH_3COO^-\ (aq)$ **AND** addition of alkali causes equilibrium to move to the right ✓ <<When small amount of strong acid is added>> : $CH_3COO^-\ (aq) + H^+(aq) \rightarrow CH_3COOH\ (aq)$ ✓ **OR** $CH_3COOH\ (aq) \rightleftharpoons H^+\ (aq) + CH_3COO^-\ (aq)$ **AND** equilibrium shifts to the ethanoic acid side (left) ✓	*Accept "HA" for the acid* *Award [1 max] for correct explanations of buffering with addition of acids **AND** bases without equilibrium equations* *(N19/P2/TZ0/Qn5b(ii) and M19/P2/TZ1/Qn5d(iii))*	2
7.	b		«$K_a = 10^{-4.76} = 1.7 \times 10^{-5}$» «$K_w = K_a \cdot K_b = 1.0 \times 10^{-14} = 1.7 \times 10^{-5} \times K_b$» «$K_b$ =» 5.8×10^{-10} ✓	*Accept answers between 5.7–5.9 x 10^{-10}.*	1
7.	c		$[H^+]$ <<= $\sqrt{K_a \times [CH_3COOH]} = \sqrt{10^{-4.76} \times 0.0100}$ >> = 4.168 x 10^{-4} <<mol dm^{-3}>> ✓ pH = 3.38 ✓	*Accept pH = 3.37 – 3.39* *Award [2] for correct final answer.* *Accept other calculation methods*	3

			Assumption: ionisation is << 0.0100 so 0.0100 - $[A^-] \approx 0.0100$ *OR* $[HA]_{eqm} = [HA]_{initial}$ *OR* all H^+ ions in the solution come from the acid «and not from the self-ionisation of water». *OR* $[H^+] = [CH_3COO^-]$ ✓	*Do not accept partial dissociation*	
7.	d		«n(KOH) = 0.02075 dm^3 x 1.00 mol dm^{-3} =» 0.0208 «mol» ✓ «n(KOH) = n(CH_3COOH)» «$[CH_3COOH] = \frac{0.0208\ mol}{0.02500\ dm^3}$ =» 0.830 «mol dm^{-3}» ✓	*Award [2] for correct final answer.*	2
7.	e	i	systematic «error» ✓		1
7.	e	ii	[CH_3COOH] would be higher ✓ actual [KOH] is lower «than the value in calculation» *OR* larger volume of KOH «solution» needed to neutralize the acid ✓	*Accept KOH partially neutralised by CO_2 from air.*	2
				Total	15

Question			Answers	Notes	Total
8.	a		Al/aluminium «electrode» ***AND*** aluminium nitrate/$Al(NO_3)_3$ /Al^{3+} on left ✓ Sn/tin «electrode» ***AND*** tin«(II)» nitrate/$Sn(NO_2)_2$ /Sn^{2+} on right ✓ salt bridge ***AND*** voltmeter/V/lightbulb ✓	*Award **[1]** if M1 and M2 are reversed.* *Award **[1]** for two correctly labelled solutions **OR** two correctly labelled electrodes for M1 and M2.* *Accept a specific salt for "salt bridge".* *Accept other circuit components such as ammeter/A, fan, buzzer, resistor/heating element/R/Ω.*	3
8.	b		$3Sn^{2+}$ (aq) + 2Al (s) → 3Sn (s) + $2Al^{3+}$ (aq) ***OR*** $3Sn(NO_3)_2$ (aq) + 2Al (s) → 3Sn (s) + $2Al(NO_3)_3$ (aq) ✓	*If half-cells are reversed in (a) then the equation must be reversed to award the mark. (ecf)* *Do **not** penalize equilibrium arrows.*	1
8.	c		«1.66 + (−0.14) = +»1.52 «V» ✓	*Calculation must be consistent with equation given in 8b*	1
8.	d		«$\Delta G^{\ominus} = -nFE^{\ominus} = -6 \times 9.65 \times 10^4 \times 1.52$ =» −880080 «J mol^{-1}» ***OR*** 6 «electrons» ✓ «$\frac{-880080}{1000}$ =» −880 «kJ» ✓	*Award **[1]** for "«+»880".* *Award **[2]** for correct final answer*	2
				Total	7

Question			Answers	Notes	Total
9.	a		*Any one of:* «regular» hexagon ***OR*** all «H–C–C/C-C-C» angles equal/120° ✓ all C–C bond lengths equal/intermediate between double and single ***OR*** bond order 1.5 ✓		1
9.	b		 ✓		1
9.	c	i	$2H_2SO_4 + HNO_3 \rightleftharpoons NO_2^+ + 2HSO_4^- + H_3O^+$ ✓	*Accept a single arrow instead of an equilibrium sign.* *Accept "$H_2SO_4 + HNO_3 \rightleftharpoons NO_2^+ + HSO_4^- + H_2O$".* *Accept "$H_2SO_4 + HNO_3 \rightleftharpoons H_2NO_3^+ + HSO_4^-$".* *Accept equivalent two step reactions in which sulfuric acid first behaves as a strong acid and protonates the nitric acid, before behaving as a dehydrating agent removing water from it.*	1

Question			Answers	Notes	Total
9.	c	ii	 curly arrow going from benzene ring to N «of $^+NO_2/NO_2$'» ✓ carbocation with correct formula and positive charge on ring ✓ curly arrow going from C–H bond to benzene ring of cation ✓ formation of organic product nitrobenzene ***AND*** H^+ ✓	*Accept mechanism with corresponding Kekulé structures.* *Do **not** accept a circle in M2 or M3.* *Accept first arrow starting either inside the circle or on the circle.* *If Kekulé structure used, first arrow must start on the double bond.* *M2 may be awarded from correct diagram for M3.* *M4: Accept "$C_6H_5NO_2 + H_2SO_4$" if HSO_4^- used in M3.*	4
9.	d		*Stage one:* $C_6H_5NO_2$ (l) + 3Sn (s) + $7H^+$ (aq) → $C_6H_5NH_3^+$ (aq) + $3Sn^{2+}$ (aq) + $2H_2O$ (l) ✓ *Stage two:* $C_6H_5NH_3^+$ (aq) + OH^- (aq) → $C_5H_5NH_2$ (l) + H_2O (l) ✓		2
				Total	9