Question	Expected Answers	Marks
1 (a) (i)	has at least one ion with a partially filled d-orbital	1
(ii)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3\ 4s^2$	1
(b) (i)	$Fe(OH)_2$ green	2
	$Fe(OH)_3$ / $Fe_2O_3.xH_2O$ brown/red-brown/rust coloured/orange-brown	2
	both solid	1
(ii)	$[Cu(H_2O)_6]^{2+} + 2OH^- \rightarrow Cu(OH)_2 + 6H_2O$ / $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2$	1
	$Cu(OH)_2$ obtains 1 mark if not part of balanced equation	1
	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$	1
	$[Cu(NH_3)_4(H_2O)_2]^{2+}$ / $[Cu(NH_3)_4]^{2+}$ =1mark if not part of balanced equation	1
	N.B. Correctly balanced equations obtain both marks	
	[Total: 11]	

Question	Expected Answers	Marks
2 (a)	absorbs violet/blue / 400 nm - 450 nm No other absorbance below 650 nm	1
(b)	absorbs the complementary colour it transmits	1
(c)	K : Cr : F = 0.818 : 0.410 : 2.46 (correct ratios obtain this mark)	1
	2K : 1Cr : 6F / K_2CrF_6	1
(d)	F^- / fluoride	1
	Don't accept fluorine or F	
	[Total: 5]	

Question	Expected Answers	Marks
3 (a)	*correctly labelled:* atomisation of chlorine + atomisation of caesium	1
	1^{st} ionisation energy + 1^{st} electron affinity	1
	formation of CsCl + LE	1
(b)	-443 = + 76 + (+122) + (+376) + (-349) + LE	1
	LE = -668 kJ mol^{-1} (allow ecf here if 1 mistake only in step 1)	1
(c)	Na^+ smaller than Cs^+ (don't accept sodium smaller first time)	1
	Na^+ has a larger charge density	1
	attracts the anion/Cl^- more strongly/ sodium chloride has the stronger bonding	1
(d)	dissolves / no reaction *do not accept "nothing"*	1
	colourless / neutral / pH 7	1
(e)	add aqueous $AgNO_3$	1
	chloride gives a white ppt	1
	iodide gives a yellow ppt	1
	Alternative answer	
	Pass chlorine/use NaOCl & HCl	
	No change with CsCl	
	Iodine displaced/brown solution with CsI	

[Total: 13]

Question	Expected Answers	Marks
4 (a)	$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$	2
	1 mark for correct species, 1 mark for correct balancing including electrons if present	
(b)	amount of $C_2O_4^{2-}$ = (25.0/1000) × 0.0400 = 0.001 mol	1
	amount of MnO_4^- required = 0.001 × (2/5) = 0.0004 mol	1
	vol of MnO_4^- required = 0.0004/0.0200 × 1000 = 20 cm^3 / 0.02 dm^3	1
	(Allow ecf on parts 2 & 3)	

[Total 5]

Question	Expected Answers	Marks
1 (a)	coordination number 4	1
	oxidation state +2	1
(b)	$[Cu(NH_3)_4(H_2O)_2]^{2+}$	
	colour dark blue / deep blue / Royal blue	1
	shape octahedral	1
	$[Cu(H_2O)_6]^{2+}$	
	colour blue	1
	shape octahedral	1
	$[CuCl_4]^{2-}$	
	colour yellow / green	1
	shape tetrahedral	1
(c) (i)	$[CuCl_4]^{2-}$	1
(ii)	the ion transmits yellow/green light / complementary colour	1
(d) (i)	concentrated / excess	1
	NH_3 (not NH_4^+)	1
	Allow from equation	
(ii)	concentrated	1
	HCl / NaCl	1
	Allow from equation	
		[Total 14]

Question			Expected Answers	Marks
2	(a)		$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$	1
	(b)	(i)	octahedral	1
		(ii)	oxidises easily/reacts with air	1
	(c)	(i)	Ti^{4+} has no electrons in the d-orbital	1
			Ti^{3+} has 1 electron in the d-orbital	1
			colour is associated with partly filled d-orbital / d-orbital electron absorbs energy from the visible/coloured region	1
		(ii)	white paint / pigment. Accept paint but **NOT** dyes	1
			[Total: 7]	

Question		Expected Answers	Marks
3	(a)	+2	1
	(b)	0.0022 mol	1
	(c)	0.0011 mol	1
	(d)	0.0022 mol	1
	(e)	8.8×10^{-2} mol dm^{-3} (allow ecf on parts c, d and e)	1
		[Total: 5]	

Question			Expected Answers	Marks
4	(a)	(i)	Cr electrode + $Cr^{3+}(aq)$	1
			Cd electrode + $Cd^{2+}(aq)$	1
			salt bridge + 1 mol dm^{-3} solutions + complete circuit	1
		(ii)	Cr → Cd (on wire, not through salt bridge)	1
		(iii)	oxidation takes place at Cr/Cr loses electrons	1
			because it has the most negative E^{θ} value/is the anode/is negatively charged	1
			Allow reverse idea relating to cadmium. Don't accept reference to electronegativity	
	(b)		$2Cr + 3Cd^{2+} \rightarrow 3Cd + 2Cr^{3+}$	1
	(c)	(i)	0.34 (V)	1
		(ii)	non-standard conditions / concentration is no longer 1mol.dm^{-3}	1
			Don't accept concentration is decreased	
			[Total: 9]	

Question	Expected Answers	Marks
5 (a)	optical isomerism/chirality/description of non super-imposable mirror images	1
	showing the two isomers	1
	example	1
	geometrical isomerism / cis & trans isomerism	1
	showing the two isomers	1
	example	1
(b)	add acid to CrO_4^{2-} to get $Cr_2O_7^{2-}$ or visa versa	1
	correct colours for both	1
	$2\ CrO_4^{2-} + H^+ \rightarrow Cr_2O_7^{2-} + OH^-$ / $2\ CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$	1
	QWC – SPAG?	1

[Total: 10]

1. (a)(i) $K_c = \frac{[NO_2(g)]^2}{[N_2O_4(g)]}$ [1]

(ii) $K_c = \frac{(0.0150)^2}{(0.0390)} = 5.77 \times 10^{-3}$ ✓ mol dm^{-3} ✓ accept 5.76923 to 5.8×10^{-3}

If (i) is upside down: $\frac{[N_2O_4(g)]}{[NO_2(g)]^2}$, then ans = 173 ✓ dm^3 mol^{-1} ✓ accept 173.33333.....to 170

if no square in (i): $\frac{[NO_2(g)]}{[N_2O_4(g)]}$, then ans = 0.384615..✓ no units ✓ (must be stated)

if no square in (i) and inverse: $\frac{[N_2O_4(g)]}{[NO_2(g)]}$, 2.6 ✓ no units ✓ (must be stated)

[2]

(b) $\Delta H = (2 \times 33) - (9)$ ✓ $= (+)57$ kJ mol^{-1} ✓

common errors: −57 ✓× +24 ✓× +75 ✓× −24 ×× [2]

(c) *change* more NO_2 / less N_2O_4 ✓

explanation equilibrium position ⟶ right or forwards / K_c increases ✓

reaction is endothermic ✓

THIS ANSWER IS CONSEQUENTIAL ON SIGN OF THE ANSWER TO (i)

BUT, a candidate interpreting a '+' enthalpy change as 'exothermic' (or vice versa) will lose the 3rd mark but the 2 'logic marks' before are still consequentially available.

[3]

(d) 1 mol N_2O_4 reacts with 2 mol NaOH ✓

amount of NaOH required = 0.00930 mol ✓

volume NaOH = 1000 x 0.0093/0.300 = 31.0 cm^3 / 0.0310 dm^3 ✓

Common errors

3.1×10^x (where x is incorrect) ✓✓×

15.5 cm^3 / 0.0155 dm^3 ✓✓×

1.55×10^x (where x is incorrect) ✓××

62 cm^3 / 0.062 dm^3 ✓✓×

6.2×10^x (where x is incorrect) ✓×× [3]

[Total: 11]

2. (a) $k = \frac{\text{rate}}{[H_2(g)][NO(g)]^2}$ ✓

$k = 8.3 \times 10^4$ ✓ $dm^6\ mol^{-2}\ s^{-1}$ ✓ calculator value: $8.33333.... \times 10^4$

If [NO] is not squared: $\frac{\text{rate}}{[H_2(g)][NO(g)]}$ ×, ans = 250 ✓ units: $dm^3\ mol^{-1}\ s^{-1}$ ✓

If the expression is upside down: $\frac{[H_2(g)][NO(g)]^2}{\text{rate}}$ ×, ans = 1.2×10^{-5} ✓ units: $mol^2\ s\ dm^{-6}$ ✓

upside down and not squared: $\frac{[H_2(g)][NO(g)]}{\text{rate}}$ ××, ans = 0.004 mol s dm^{-3} ✓ [3]

(b)(i) *effect on rate* x 2 ✓

reason 1st order wrt $H_2(g)$ ✓ [2]

(ii) *effect on rate* x 1/4 ✓

reason 2nd order wrt NO(g) ✓

[2]

(iii) *effect on rate* x 27 ✓

[1]

(c)(i) slowest step ✓

[1]

(ii) step 1 (RDS) $H_2(g) + 2\ NO(g)$ ✓ $\longrightarrow N_2O(g) + H_2O(l)$

step 2 $H_2(g) + N_2O(g) \longrightarrow N_2(g) + H_2O(l)$ rest of equations ✓

[2]

(d)(i) NH_3, –3 ✓

NO, +2 ✓

HNO_3 +5 ✓ [3]

(ii) $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$

products + reactants ⟶ 1 mark; balancing ⟶ 1 mark ✓ ✓

[2]

(iii) molar masses NH_3 = 17; HNO_3 = 63 ✓

mass = 700 000 x 17/63 = 1.89×10^5 tonnes ✓ calc value $1.888888.... \times 10^5$

ans: mark could be consequential on incorrect molar masses. [2]

[Total: 18]

3. (a) Empirical formula = C : H : O = 40.0/12 : 6.7/1 : 53.3/16 = 3.33 : 6.7 : 3.33 ✓

= CH_2O ✓

mass CH_2O = 30; M_r = 90 ∴ molecular formula = $C_3H_6O_3$ ✓ [3]

(b)

$$K_a = \frac{[H^+(aq)]\,[A^-(aq)]}{[HA(aq)]} \Big/ \frac{[H^+(aq)]^2}{[HA(aq)]}$$ ✓

$$\therefore 1.2 \times 10^{-5} = \frac{[H^+(aq)]^2}{1.5}$$

$[H^+(aq)] = \sqrt{\{(1.2 \times 10^{-5}) \times (1.5)\}} = 4.2 \times 10^{-3}$ mol dm^{-3} ✓

pH = $-\log[H^+(aq)]$ ✓ = $-\log 4.2 \times 10^{-3}$ = 2.4 / 2.37 ✓

4 marks: K_a expression✓;

$[H^+]$✓;

pH expression✓;

calculation of pH from $[H^+]$ (ecf) ✓

Common error: Without square root, answer is 4.7/ 4.7447... ✓✓✓x

[4]

(c)(i) A solution that minimises changes/resists change in pH after addition of acid/alkali ✓

NOT 'maintains constant pH' or 'cancel out' [1]

(ii) $CH_3COOH \rightleftharpoons H^+ + CH_3COO^-$ / $CH_3COOH + H_2O \rightleftharpoons H_3O^+ + CH_3COO^-$ [1]

(iii) The weak acid or CH_3COOH reacts with added alkali / added alkali reacts with H^+ ✓

The base or CH_3COO^- reacts with added acid ✓

Direction of movement indicated for one change / indication of the products formed for one change ✓

[3]

(d) *effect on pH* increases ✓

explanation equilibrium ⟶ left ✓

H^+ removed by CH_3COO^- ✓

[3]

[Total: 15]

4. (a) ***Pressure: 3 marks***

high pressure ✓ fewer gaseous moles on right ✓

Compromise: pressure used but too much is requires too much energy/high costs/causes safety issues/thick pipes ✓

Temperature: 4 marks

low temperature ✓ reaction is exothermic ✓

Increased temperature needed to increase the rate/low temperature gives a slow rate ✓

Compromise: idea of a compromise between rate and equilibrium amount ✓

7 marking points ⟶ 6 max

Clear, well-organised, using specialist terms ✓

[7]

(b)(i)

what citric acid does: citric acid dissociates ✓

H^+ released / H_2O accepts H^+/behaves as a base ✓

equation: $H_3A + 3H_2O \longrightarrow 3H_3O^+ + A^{3-}$

or $H_3A \longrightarrow 3H^+ + A^{3-}$

or $H_3A + H_2O \longrightarrow H_3O^+ + H_2A^-$

or $H_3A \longrightarrow H^+ + H_2A^-$ ✓ (or other intermediate dissociation)

The equation alone will also score the 2 'what citric acid does' marks.

how H^+ reacts: H^+ now reacts with HCO_3^- ions/$NaHCO_3$ ✓

equation: $H^+ + HCO_3^- \longrightarrow H_2O + CO_2$ ✓

The equation alone will also score the 'how H^+ reacts' mark.

5 marks ⟶ [4] max

(ii) Molar mass of $NaHCO_3$ = 84.0 ✓

amount of $NaHCO_3$ = 0.5/84.0 = 5.95×10^{-3} mol ✓

3 mol $NaHCO_3$ reacts with 1 mol citric acid ✓

amount of citric acid = $5.95 \times 10^{-3}/3 = 1.98 \times 10^{-3}$ mol ✓

mass of citric acid required = $1.98 \times 10^{-3} \times 192 = 0.380$ g ✓

(allow 0.4 g)

Answer of 0.127g / 0.12698 g from dividing by 3 twice ⟶ ✓✓✓✓x

[5]

[Total: 16]