1. (a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

Accept multiples.

Ignore state symbols, even if incorrect.

1

(b) Hazard acid corrosive **or** hydrogen flammable / explosive

Accept 'iron(II) sulfate / sulfuric acid an irritant'.

1

Precaution gloves or eye protection **or** avoid naked flames / spark

Allow 'if reagent contacts skin wash off immediately' or answers to that effect instead of gloves.

Do not allow 'wipe up spillages'.

Ignore 'lab coat' or 'use of fume cupboard' or 'do not ingest chemicals'.

1

[3]

2. (a) $Na_2CrO_4 + Pb(NO_3)_2 \rightarrow PbCrO_4 + 2NaNO_3$

Allow multiples, including fractions.

Allow $Pb^{2+} + CrO_4^{2-} \rightarrow PbCrO_4$

Ignore state symbols.

1

(b) Is not washed away / dissolved by <u>rain</u>

Ignore reference to insolubility.

Allow 'prevents toxic compounds getting into water supplies'.

1

(c) Will not react with <u>oxygen in the air</u>

1

(d) Compound is toxic / poisonous

Ignore 'harmful' or 'dangerous'.

Do not allow 'corrosive'.

1

[4]

3. (a) $Mg^{2+}(g) + 2e^- + 2Cl(g)$ (This is the only answer for the top line) (1)

$Mg^{2+}(g) + 2e^- + Cl_2(g)$ (1)

$Mg^{+}(g) + e^- + Cl_2(g)$ (1)

$Mg(g) + Cl_2(g)$ (state symbols and electrons essential) (1)

(Note Cl_2 to 2Cl can be in any order but Mg must be in sequence)

(b) I.E. + 642 + 150 + 736 + 2 × 121 = 2 × 364 + 2493 *numbers & signs* (1)

Factors of 2 (1)

I.E. = (+)1451 (kJ mol^{-1}) (Ignore units even if wrong) (1)

(Note +1208, +1087, +1572 Each score one only)

(c)		*ΔH = -ΔH(lattice formation) + $\Sigma\Delta H$(hydration) (or cycle with state symbols, numbers or labels)*		(1)
		= 2493 – 1920 – 2 × 364		(1)
		= -155		(1)
		(Note MgCl score zero; +155 scores 1/3)		
(d)	(i)	Increase in disorder on dissolving or ΔS positive		(1)
		ΔG negative or $T\Delta S > \Delta H$		(1)
	(ii)	Moles of NH_4Cl = 2/53.5 = 0.0374 (Wrong compound loses first 2, wrong M_r loses 1)		(1)
		Heat absorbed = 15 × 0.0374 = 0.561 (mark is for × 15)		(1)
		Q = $m\ c\ \Delta T$		(1)
		$\Delta T = Q/mc$ = (0.561×1000)/(50×4.2) = 2.6 (°C)		(1)
		(allow 2.5 to 2.7)(can use 52) (ignore units, answer must be at least 2 sig figs)		
		(Note;may not use moles (loses first 2 marks) so ΔT = (15×1000)/(50×4.2) So answers of 71.4 and 68.7 score last 2 out of first 4)		
		Final temperature = 20 – 2.6 = 17.4 °C (Answer is for 20 – previous ans; must be < 20)		(1)
		(allow no units for temperature, penalise wrong units)		

[17]

4. (a)	(i)	kPa^{-1} not 1/kPa			(1)
	(ii)	$pO_2 = \dfrac{(p_{SO_3})^2}{(p_{SO_2})^2 K_p}$	one mark for correct rearrangement of expression to give pO_2 = ….		(1)
		$= \dfrac{90.8^2}{10.6^2 \ \text{x}\ 1.42}$	one mark for insertion of correct numbers into acorrect expression *These can be in either order*		(1)
		= 51.7 (allow 51.6 – 51.9)			(1)
(b)	(i)	increase			(1)
		equilibrium moves to fewer gas moles or fewer moles on RHS			(1)
	(ii)	none			(1)
	(iii)	T_2			(1)
		equilibrium moves in endothermic direction or to LHS or forward reaction is exothermic…			(1)

(c) (i) 0.08 (NOT 0.085) (1)

(ii) pp = mole fraction × total pressure (1)

(iii) mark consequentially on (i) — OR one mark for correct rearrangement of expression to give P = …. (1)

$$K_p = \frac{(\text{mol fn } SO_3)^2 \text{ x } P^2}{[(\text{mol fn } SO_2)^2 \text{ x } P^2][(\text{mol fn } O_2) \text{ x } P]}$$

must specify substances

$$P = \frac{0.75^2}{0.17^2 \text{ x } 0.08 \text{ x } 1.42}$$

one mark for insertion of correct numbers into a correct expression (1)
These steps can be in either order

= 171 (kPa) (1)

[14]

5.

(a)	(i)	– log[H⁺];	1	Allow log 1/[H⁺] or full definition in words. Penalise ( )
	(ii)	0.82;	1	Penalise pH to <2dp> once in the paper

(b)	(i)	mol KOH = $\frac{60}{1000} \times 0.0850 = 5.1 \times 10^{-3}$;	1	Mark for answer
	(ii)	mol HCl = $\frac{30}{1000} \times 0.150 = 4.5 \times 10^{-3}$;	1	Mark for answer
	(iii)	**M1** XS mol KOH = 6.0×10^{-4} if XS acid can only score b(i), b(ii) and M2 (vol);	1	Conseq on their b(i) – b(ii)
		M2 total volume = 90 cm^3;	1	If vol missed or wrong (apart from obvious AE), lose M2 and next mark gained, e.g. if vol = 60 cm^3 lose M2 and M3 (0.010) but can gain M4 for pOH = 2.00 and M5 for pH = 12.00 if no vol: M4 gained for $[H^+] = 1.67 \times 10^{-11}$ or pOH = 3.22 M5 for pH = 10.78
		M3 $[OH^-] = 6.0 \times 10^{-4} \times \frac{1000}{90}$ ($= 6.67 \times 10^{-3}$ or 6.7×10^{-3});	1	AE (-1) if 1000 missed (pH = 8.82) AE (-1) if 1000/90 upside down, (pH = 9.73) If wrong method (e.g addition of moles) only score max 2 for M1 and M2
		M4 $[H^+] = \frac{10^{-14}}{6.67 \times 10^{-3}}$ (or 1.50×10^{-12} or 1.49×10^{-12}); ***OR*** pOH = 2.18; ***OR*** pOH = 2.17;	1	Must involve substitution of numbers not just rearrangement of K_w If no use of Kw or pOH – no further marks (ie pH =2.18 gets M1, M2, M3 only)
		M5 pH = 11.82; ***OR*** 11.83;	1	Penalise pH to <2dp> once in the paper.

[9]

6. (a) $HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$

or

$H_2O + HCO_3^- \rightleftharpoons CO_3^{2-} + H_3O^+$

Must have equilibrium sign but mark on to (b)

Ignore state symbols

1

(b) Acid: Increase in concentration of H^+ ions, equilibrium moves to the left.

Allow H^+ ions react with carbonate ions (to form HCO_3^-)

1

Alkali: OH^- reacts with H^+ ions, equilibrium moves to the right (to replace the H^+ ions)

1

Concentration of H^+ remains (almost) constant

1

[4]

7. (a) (i) **B** 1

C 1

A 1

(ii) cresolphthalein or thymolphthalein 1

(b) pH = -log[H^+] 1

$K_a = \frac{[H^+]^2}{[CH_3COOH]}$ or [H^+] = [A^-] 1

[H^+] = √□1.74 × 10^{-5} × 0.15 (or 1.62 × 10^{-3}) 1

pH = 2.79 (penalise 1 dp or more than 2dp once in the qu) 1

[8]

8. (a) (i) W Pt (or in words) (1)

X KCl, NH_4Cl etc (allow any simple soluble salt and ignore water, paper, agar etc) (1)

Y Mg (1)

Z $MgCl_2$ (1)

(aq not essential)

(allow any identified soluble Mg salt)

(ii) $Pt|H_2(g)|H^+(aq)||Mg^{2+}(aq)|Mg$

(allow $Mg|Mg^{2+}(aq)||H^+(aq)|H_2|Pt$) (1)

Species

(ignore state symbols)

(allow any coefficients)

Correct order (1)

(order is consequential on correct species)

(can score this mark (not first mark) if phase boundary solidus omitted)

(If Pt omitted max 1)

(b) (i) 0.84 (V) (1)

(ii) (+)3 (1)

(or III)

(or Mn^{3+} or Mn(III))

(iii) $2MnO_2 + 2H_2O + Zn \rightarrow 2MnO(OH) + 2OH^- + Zn^{2+}$ (1)

(allow multiples)

(allow $Zn(OH)_2$)

(arrow can be equilibrium arrow)

(iv) *Oxidising agent* MnO_2 (1)

(allow in words manganese oxide)

Reducing agent Zn (1)

(v) Zn (or MnO_2) used up (1)

(or concentration of products increases)

(or electrode(s) worn away)

(allow polarisation or explanation in terms of ion migration)

(note if equation reversed allow conseq i.e. Zn^{2+} or MnO(OH) used up)

(c) (i) $4H^+ + SO_4^{2-} + 2e^- \rightarrow SO_2 + 2H_2O$ (1)

(or $2H^+ + H_2SO_4$ etc)

$2Br^- \rightarrow Br_2 + 2e^-$ (1)

$4H^+ + SO_4^{2-} + 2Br^- \rightarrow SO_2 + 2H_2O + Br_2$ (1)

(or $2H_2SO_4 + 2KBr \rightarrow K_2SO_4 + SO_2 + 2H_2O + Br_2$)

(allow production of SO_3^{2-} for last mark but not for half equation i.e. 1/2)

(ii) H_2SO_4 cannot oxidise Cl^- (1)

(or Cl^- ions (or KCl) cannot reduce H_2SO_4)

(or Cl_2 strong(er) oxidising agent (than H_2SO_4))

(or Cl^- weak reducing agent)

(allow any correct E^0 argument)

$H_2SO_4 + KCl \rightarrow KHSO_4 + HCl$ (1)

(or $H_2SO_4 + 2KCl \rightarrow K_2SO_4 + 2HCl$)

(or $H^+ + Cl^- \rightarrow HCl$ or any correct equation to give HCl)

[17]

9. (a) (i) An atom, ion or molecule which can donate a lone electron pair

1

(ii) A central metal ion/species surrounded by co-ordinately bonded ligands or ion in which co-ordination number exceeds oxidation state

1

(iii) The number of co-ordinate bonds formed to a central metal ion or number of electron pairs donated or donor atoms

1

(b) (i) *Allow the reverse of each substitution*

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$

Complex ions

1

Balanced

1

Allow partial substitution

(ii) $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow CoCl_4^{2-} + 6H_2O$

Complex ions

1

Balanced

or H_2O or NH_3 or $C_2O_4^{2-}$ by Cl^-

1

eg. (iii) $[Co(H_2O)_6]^{2+} + 3C_2O_4^{2-} \rightarrow [Co(C_2O_4)_3]^{4-} + 6H_2O$

Complex ions

1

Balanced

1

Allow all substitution except

(i) NH_3 by H_2O

(ii) more than $2Cl^-$ substituted for NH_3 or H_2O

eg. (iv) $[Co(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [Co(EDTA)]^{2-} + 6H_2O$

Complex ions

1

Balanced

or H_2O or NH_3 by $C_2O_4^{2-}$ and NH_3 or Cl^- by $EDTA^{4-}$

1

(c) (i) $[Fe(H_2O)_6]^{2+}$

1

(ii) $Fe(OH)_2$ or $Fe(OH)_2(H_2O)_x$ where x = 0 to 4

1

(iii) Fe^{2+} is oxidised to Fe^{3+} or $Fe(OH)_3$

1

By oxygen in the air

1

[15]

10. (a) Ti(IV) [Ar]

Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **1**

Ti(III) [Ar]$3d^1$

Or $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1$ **1**

Ti(III) has a d electron that can be excited to a higher level

Allow idea that d electrons can be excited to another level (or move between levels) **1**

Absorbs one colour of light from white light

Allow idea that light is absorbed **1**

Ti(IV) has no d electron so no electron transition with energy equal to that of visible light

Allow Ti(IV) has no d electrons **1**

(b) $[Cu(NH_3)_4(H_2O)_2]^{2+}$ **1**

$[CuCl_4]^{2-}$ **1**

(c) (i) Rapid determination of concentration

Or easy to get many readings **1**

Does not use up any of the reagent/does not interfere with the reaction

Or possible to measure very low concentrations **1**

(ii) Curve starts with small gradient (low rate) **1**

Because negative ions collide so E_a high **1**

Curve gets steeper **1**

Because autocatalyst (Mn^{2+}) formed **1**

Curve levels out approaching time axis

Can score this mark and next one ONLY with simple curve (that is curve with gradually decreasing gradient) **1**

Because MnO_4^- ions used up

5 max **1**

[14]