Q1.

1 **(a)** The EMF of a cell made up of the test electrode and a <u>standard hydrogen electrode</u>. [1]

EMF measured under standard conditions of T, P and concentration [1]

2

(b) **(i)** $E_{left} = E_{right} - E_{cell}$ = 0.34 - 0.76 = **-0.42 (V)** [1]

(ii) $\longrightarrow$ (arrow from left to right) [1]

(iii) I pink/red solid/ppt *or* copper will be formed *or* blue solution fades *or* M dissolves/corrodes [1]

$Cu^{2+} + M \rightarrow Cu + M^{2+}$ [1]

II hydrogen/gas evolved *or* M dissolves (do not allow "M dissolves" for [2] marks in both I and II) [1]

$M + 2H^{+} \rightarrow M^{2+} + H_2$ [1]

6

(c) **(i)** polarity of d. c. source: $\ominus$ is on the left, $\oplus$ is on the right [1]

electrolyte is $Cu^{2+}(aq)/CuSO_4/CuCl_2/Cu(NO_3)_2$ etc. *or* name [1]

(ii) moles of Cu = 0.5/63.5 = 7.87×10^{-3} [1]

moles of e^- = $2 \times 7.87 \times 10^{-3}$ = 1.57×10^{-2}

no. of coulombs = $96500 \times 1.57 \times 10^{-2}$ = 1517 (C) [1] ecf in n(e^-)

time = 1520/0.5 = 5034 seconds = 50.7 min [1] ecf in coulombs

5

Total 13

Q2.

1 (a) (i) Ammeter/galvanometer [1]

Clock/watch/timer (**or** rheostat) [1]
(For items above 2 in number, e.g. voltmeter, penalise **[1]**)

(ii) Diagram to show ammeter (allow symbol) in circuit, and [1]
complete circuit with ⊖ terminal of power pack connected to LH electrode [1]

(iii) Volume/amount of hydrogen/gas [1]

Time [1]

Current/amps/ammeter reading
(ignore extra measurements) [1]

Part (a): [7]

(b) (i) F = L x e [1]

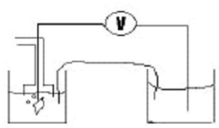
(ii) L = $9.63 \times 10^4 / 1.6 \times 10^{-19}$ = $\mathbf{6.02 \times 10^{23}}$ (**must** show working) [1]

Allow 6.0 but not 6 or 6.01 **Part (b): [2]**

Total: [9]

Q3.

1 (a)



salt bridge + voltmeter [1]
zinc metal + Zn^{2+} [1]
H_2 (in, *not* out) + H^+ [1]
Pt electrode [1]
all solutions at 1 mol dm^{-3} [1]
T = 298K *or* 25°C [1] **[6]**

(b)

conditions	product at anode	product at cathode
$ZnCl_2$(l)	*(chlorine)*	***zinc* [1]**
$ZnCl_2$(conc aq)	***chlorine* [1]**	*(H_2 or zinc) (ignore)*
$ZnCl_2$(dil aq)	***oxygen* [1]**	***hydrogen* [1]**

[1] for each product in correct place [4] **[4]**

Q4.

1 (a) (i) **A** is Cl_2/chlorine [1]

B is NaCl *or* HCl *or* Cl^- [or words], etc. [1]

C is salt bridge or KCl/KNO_3, etc. [1]

D is platinum/Pt [1]

E is Fe^{2+} + Fe^{3+} or mixture of Fe(II) + Fe(III) salts [1]

mention of standard conditions ([Cl^-] of 1 mol dm^{-3} *or* Cl_2 at 1 atmos *or* T = 25°C/298 K) [1]

(ii) $E^\circ = E^\circ_R - E^\circ_L = 0.77 - 1.36 = (-)$**0.59** (V) (ignore sign) [1]

(since R.H. electrode is negative) electrons flow (from right) **to left** *or* to the chlorine electrode *or* anticlockwise *or* from (beaker) **E** to (beaker) **B** [1] **[8]**

(b) (i) $\Delta H = 3 \times (-167.2) + (-48.5) - (-399.5)$ [1]
$= $ **−150.6** *or* **151** (kJ mol^{-1}) [1]
(correct ans [2])

(ii) $2Fe^{3+} + Cu \longrightarrow 2Fe^{2+} + Cu^{2+}$ [1]
(*or* molecular: $2FeCl_3 + Cu \longrightarrow 2FeCl_2 + CuCl_2$)

$E^\circ = 0.77 - 0.34 = (+)$ **0.43** (V) [1]
(no mark for −0.43V) **[4]**

[Total: 12 max 11]

Q5.

2 **(a)** NaCl: steamy fumes [1]

$NaCl + H_2SO_4 \longrightarrow NaHSO_4 + HCl$ (*or* ionic, i.e. without the Na^+)

or $2NaCl + H_2SO_4 \longrightarrow Na_2SO_4 + 2HCl$ [1]

NaBr: orange/brown fumes [1]

$2NaBr + 3H_2SO_4 \longrightarrow 2NaHSO_4 + 2H_2O + SO_2 + Br_2$

or $2HBr + H_2SO_4 \longrightarrow 2H_2O + SO_2 + Br_2$

(ignore equations producing HBr) [1] **[4]**

(b) relevant E° quoted: Cl_2/Cl^-, 1.36; Br_2/Br^-, 1.07; (H_2SO_4/SO_2, 0.17 – not required) [1]

Br^- is more easily oxidised because its E° is more negative

or Cl_2 is more oxidising because its E° is more positive [1] **[2]**

(c) Allow almost any reducing agent from the Data Booklet (see below) with E° less than 1.07 V.

But do not allow reducing agents that require conditions that would react with Br_2 in the absence of the reducing agent (e.g. NH_3 or OH^-), and also do not allow "reducing agents" that could produce, or act as, oxidising agents (e.g. MnO_4^{2-} and H_2O_2)

balanced equ. showing reduction of Br_2 by the chosen reducing agent

(either ionic or molecular) [1]

E° = 1.07 – (E° of reductant) = **x.xx (V)** (see below) [1] **[2]**

[Total: 8]

List of acceptable reductants with resulting E°_{cell} values

reductant	E°_{cell}/V	reductant	E°_{cell}/V	reductant	E°_{cell}/V
Ag	0.27	$Fe \Rightarrow Fe^{2+}$	1.51	Na	3.78
Al	2.73	$Fe \Rightarrow Fe^{3+}$	1.11	Ni	1.32
Ba	3.97	Fe^{2+}	0.30	Pb	1.20
Ca	3.94	H_2	1.07	SO_2	0.90
Co	1.35	I^-	0.53	$S_2O_3^{2-}$	0.98
$Cr \Rightarrow Cr^{2+}$	1.98	K	3.99	Sn	1.21
$Cr \Rightarrow Cr^{3+}$	1.81	Li	4.11	Sn^{2+}	0.92
Cr^{2+}	1.48	Mg	3.45	V	2.27
$Cu \Rightarrow Cu^+$	0.55	Mn	2.25	V^{2+}	1.33
$Cu \Rightarrow Cu^{2+}$	0.73	NO_2	0.26	V^{3+}	0.73
Cu^+	0.92	HNO_2	0.13	VO^{2+}	0.07
		NH_4^+	0.20	Zn	1.83

e.g. for Sn^{2+}: $Sn^{2+} + Br_2 \longrightarrow Sn^{4+} + 2Br^-$ [1]

E° = 1.07 – 0.15 = **0.92** V [1]

(*or* similarly for other suitable reagents)

Q6.

5 **(a)** **(i)** $E^o = 0.40 - (-0.83) = 1.23V$ (1)

(ii) $2H_2 + O_2 \longrightarrow 2H_2O$ (1)

(iii) LH electrode will become more negative (1)
RH electrode will also become more negative / less positive (1)

(iv) no change ecf from **(iii)** (1)

(v) increased conductance *or* lower cell resistance *or* increased rate of reaction (1) [6]

(b) **(i)** $E^o = 1.47 - (-0.13) = 1.60V$ (1)
(ii) $PbO_2 + Pb + 4H^+ \longrightarrow 2Pb^{2+} + 2H_2O$ (1)

(iii) $PbO_2 + Pb + 4H^+ + 2SO_4^{2-} \longrightarrow 2PbSO_4(s) + 2H_2O$ (1)

(iv) E^o_{cell} will increase (1)

as $[Pb^{2+}]$ decreases, $E_{electrode}(PbO_2)$ will become more positive, but $E_{electrode}(Pb)$ will become more negative (1) [5]

[Total: 11]

Q7.

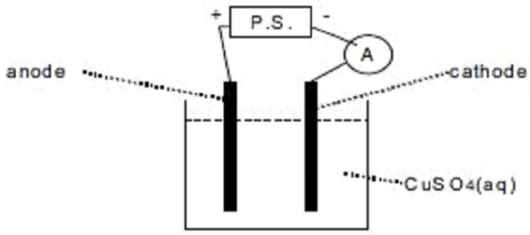
8 **(a)**	Reaction II – since electrons are used up / required / gained / received (from external circuit)	(1)	[1]
(b)	($Pb^{2+} + 2e^- \rightarrow Pb$) $E^\ominus = -0.13V$		
	($PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$) $E^\ominus = +1.47V$		
	two correct $E^\ominus$ values	(1)	
	Cell voltage is **1.6(0)** (V)	(1)	[2]
(c) **(i)**	3(+)	(1)	
(ii)	They are less heavy / poisonous / toxic / polluting *or* are safer due to no (conc) H_2SO_4 within them	(1)	[2]
(d) **(i)**	Platinum or graphite / carbon	(1)	
(ii)	They need large quantities of **compressed** gases which take up space *or* the hydrogen would need to be **liquefied** *or* the reactant is (highly) **flammable / explosive / combustible**	(1)	[2]
(e)	*Glass*: saves **energy** – the raw materials are easily accessible / cheap *or* making glass is energy-intensive	(1)	
	Steel: saves **energy** – extracting iron from the ore *or* mining the ore is energy intensive *or* saves a **resource** – iron **ore** (NOT just "iron") is becoming scarce	*either one* (1)	
	Plastics: saves a valuable / scarce **resource**: (crude) **oil / petroleum**	(1)	[3]
			[Total: 10]

Q8.

3 **(a)** L = F/e *or* F = Le [1]

[1]

(b) (i)



[allow the conventional symbol to represent (the "P.S." is not required)]

correct cell (2 electrodes + PS circuit) [1]
ammeter in series [1]
anode and cathode of the right polarity [IN WORDS] [1]
$CuSO_4$(aq) *or* $CuCl_2$(aq) *or* Cu^{2+}(aq) *or* soln *or* 1 mol dm^{-3} [1]

(ii) n(Cu) = (52.542–52.243)/63.5 = 4.71×10^{-3} mol (4.67×10^{-3}) [1]
n(e^-) required = $4.71 \times 10^{-3} \times 2$ = $\mathbf{9.42 \times 10^{-3}}$ mol (9.34×10^{-3}) ecf [1]

amount of electricity passed = 0.5 × 30 × 60 = 900 C [1]
no. of electrons passed = 900/1.6 × 10^{-19} = $\mathbf{5.625 \times 10^{21}}$ ecf [1]

no of electrons/n(e^-) = L = $5.625 \times 10^{21}/9.42 \times 10^{-3}$ = $\mathbf{5.97 \times 10^{23}}$ mol^{-1} (6.02×10^{23}) ecf [1]

(values in italics are if candidate has used A_r = 64, not 63.5. No last mark if not 3 s.f.: correct ans = [5]) **[9]**

(c)

compound	product at anode	product at cathode
AgF	O_2	Ag
$FeSO_4$	O_2	H_2
$MgBr_2$	Br_2	H_2

6 correct ⇒ [5]
5 correct⇒ [4] etc.

Names can be used instead of symbols. If the atomic symbol (e.g. Br or H or O) is used instead of the molecular formula (e.g. Br_2 etc.) then deduct [1] mark only for the whole table.
[5]

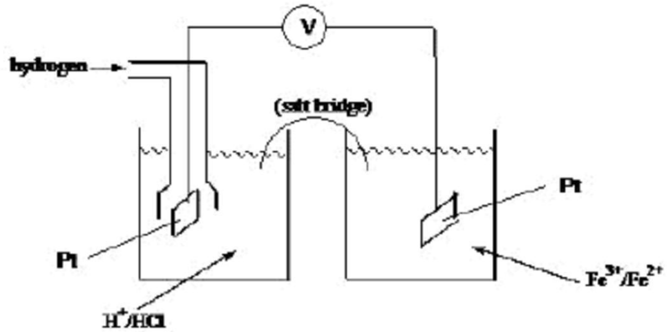
[Total: 15]

Q9.

1 **(a)** The potential of an **electrode** compared to that of a standard hydrogen electrode (SHE)
or
the EMF of a **cell** composed of the test electrode and the SHE [1]

all measurement concentrations of 1 mol dm^{-3} **and** 298K / 1 atm pressure [1]
[2]

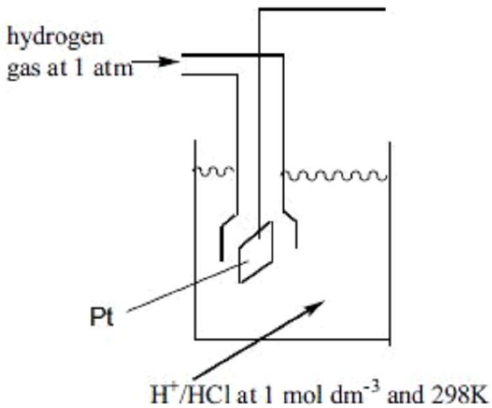
(b)



H_2 and good delivery system [1]
Fe^{2+}/Fe^{3+} solution labelled [1]
platinum electrodes (both) [1]
salt bridge and voltmeter [1]
H^+ *or* HCl *or* H_2SO_4 [1]
(acid is not sufficient)
[5]

Q10.

2 (a) (i)



H_2(g) going in (i.e. not being produced) [1]
platinum electrode in contact with solution, with H_2 bubbling over it [1]
H^+ *or* HC*l* *or* H_2SO_4 [1]
solution at 1 mol dm^{-3}(*or* 0.5 M if H_2SO_4) **and** T=298 K, p=1 atm [1]

(ii) $E^\ominus = 1.33 - (-0.41) = 1.74$ V [1]

$Cr_2O_7^{2-} + 14H^+ + 6Cr^{2+} \longrightarrow 8Cr^{3+} + 7H_2O$ [1]

(iii) Colour would change from orange [1]

to green [1]
[8]

Q11.

1 (a) A: voltmeter *or* **V** *or* potentiometer [NOT meter, ammeter, galvanometer]

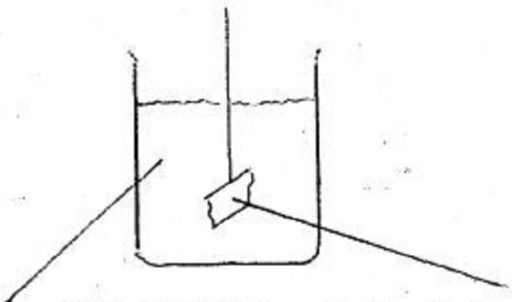
B: salt bridge *or* potassium nitrate etc.(any sensible soluble salt, e.g. chloride, sulphate, nitrate or phosphate) [NOT just bridge, or filter paper]

C: 1 mol dm^{-3} (or 1M or M) H^+ *or* H_3O^+ *or* HCl *or* HNO_3 *or* 0.5 mol dm^{-3} H_2SO_4 (allow unit activity, allow 1.18 mol dm^{-3})

[3]

3

(b) diag



2

(c) (i) E° increases/becomes more positive

(ii) E° decreases/becomes more negative/less positive (**both** correct) [1]

1

(d) (i) $2Fe^{3+} + Cu \longrightarrow 2Fe^{2+} + Cu^{2+}$ [1]

or $2FeCl_3 + Cu \longrightarrow 2FeCl_2 + CuCl_2$

or $Fe^{3+} + Cu \longrightarrow Fe^{2+} + Cu^+$ (*or* with $FeCl_3$)

(ii) E_{cell} = (0.77 - 0.34 = +)**0.43** (V) [1]

[*or* E_{cell} = (0.77 - 0.52 = +)**0.25** if Cu has been oxidised to Cu^+ in (i)]

2

(e) (i) moles(MnO_4^-) = 0.02 x 75/1000 (*or* = 1.5 x 10^{-3}) ([1] for working) [1]

moles(Fe^{2+}) = 5 x 1.5 x 10^{-3} = **7.5 x 10^{-3}**

(mark is for x 5: allow ecf if n(MnO_4^-) is wrong) [1]

(ii) moles(Cu) = (moles(Fe))/2 = 3.75 x 10^{-3} [1]

mass(Cu) = 63.5 x 3.75 x 10^{-3} = **0.24g** [1]

(ignore sig figs. allow ecf from (i) – i.e. mark is for x 63.5 *or* x 64))

(if Cu has been oxidised to Cu^+, the corresponding answers are 7.5 x 10^{-3} [1] and 0.48g [1])
(if candidates have attempted to oxidise Cu by reducing Fe^{3+} to Fe, they lose the mark in d(i), but can gain ecf marks for d(ii), (-0.56V *or* –0.38V) and also for e(ii))

4

Total: 12

Q12.

2 **(a)** $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$ (or equation ÷ 2) **[1]** **1**

(b) ⊕ **[1]** **1**

(c) 1.23 (V) (ignore sign) **[1]** **1**

(d) a better/larger salt bridge *or* a diaphragm *or* larger (area of) electrodes

or increase concentrations/pressure **[1]** **1**

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(e) time = 400 x 24 x 60 x 60 = 34 560 000 seconds **[1]**

charge = current x time = 0.01 x 34 560 000 = 345 600 C ecf **[1]**

moles of H = 345 600/96 500 = 3.6 mol ∴ mass of H = **3.6 g** ecf **[1]** **3**

(f) advantages: less pollution/CO_2/NO_x etc. *or* cleaner by-products

less dependence on fossil fuels/finite resources *any one* **[1]**

disadvantages: more expensive (to develop *or* to run)

takes up more space

poor power-to-volume ratio

hydrogen is difficult to store or to transport *any one* **[1]**

NOT hydrogen is explosive/flammable **2**

Total 9

Q13.

1 (a) M_r(AgBr) = 108 + 79.9 = 187.9 [1]

moles = $2.5 \times 10^{-12}/187.9 = 1.33 \times 10^{-14}$

no. of ions = $1.33 \times 10^{-14} \times 6 \times 10^{23}$ = **8.0×10^9 ions** (correct ans = [2]) [1]

2

(b) (i) A: platinum C: voltmeter
B: H^+(aq) *or* HC*l*(aq) *or* H_2SO_4(aq) D: silver (wire) 4 x [1]
(ignore concentration)

(ii) (As [Ag^+] decreases), the potential will decrease/become more negative [1]

(iii) K_{sp} = [Ag^+][Br^-] = $(7.1 \times 10^{-7})^2$ = **5.0(41) x 10^{-13} mol^{2}dm^{-6}** [1]

units [1]

7

Q14.

2 (a) The EMF of a cell made up of the test electrode and a standard hydrogen electrode. [1]
(*or* the EMF of the electrode compared to the S.H.E.)

EMF measured under standard conditions of T, (P) and concentration. [1]
(*or* at 298K and 1 mol dm^{-3})

2

(b) The stronger the halogen is as an oxidising agent, the more positive is its $E^\ominus$ value. [1]

Two examples of F_2/F^-, Cl_2/Cl^-; Br_2/Br^-, I_2/I^- quoted [1]

(data: F_2/F^- = +2.87V
Cl_2/Cl^- = +1.36V
Br_2/Br^- = +1.07V
I_2/I^- = +0.54V)

2

(c) (i) $H_2O_2 + 2I^- + 2H^+ \longrightarrow I_2 + 2H_2O$
or $H_2O_2 + 2KI + 2H^+ \longrightarrow 2K^+ + I_2 + 2H_2O$ [1]

$E^\ominus$ = 1.77 - 0.54 = **1.23** V [1]

(ii) $Cl_2 + SO_2 + 2H_2O \longrightarrow 2Cl^- + SO_4^{2-} + 4H^+$
or $Cl_2 + SO_2 + 2H_2O \longrightarrow 2HCl + H_2SO_4$ [1]

$E^\ominus$ = 1.36 – 0.17 = **1.19** V [1]

4

(d) since $E^\ominus(I_2/I^-)$ is +0.54V, tin will be oxidised to **Sn^{4+}** [1]
($E^\ominus$ for Sn^{2+}/Sn = -0.14V and $E^\ominus$ for Sn^{4}/Sn^{2} = +0.15V)

Thus: $Sn + 2I_2 \longrightarrow SnI_4$ [1]

2

total: 10

Q15.

3 (a) K = 22.4/39.1 = 0.573 thus ratio is: 1
Cr = 29.8/52.0 = 0.573 1
C*l* = 20.3/35.5 = 0.572 1
O = 27.5/16.0 = 1.719 3 *or* $KCrClO_3$ *(scores 2)*
[1] [1] **[2]**

(b) $K_2Cr_2O_7 + 2HCl \longrightarrow 2KCrClO_3 + H_2O$ [1]
[1]

(c) (i) redox *or* oxidation [1]

(ii) $E^{\ominus}$ data and half equations:
$Cr_2O_7^{2-} + 14H^+ + 6e^- \longrightarrow 2Cr^{3+} + 7H_2O$ $E^{\ominus} = 1.33$ V [1]
$Cl_2 + 2e^- \longrightarrow 2Cl^-$ $E^{\ominus} = 1.36$ V [1]
overall ionic equation:
$Cr_2O_7^{2-} + 6Cl^- + 14H^+ \longrightarrow 2Cr^{3+} + 3Cl_2 + 7H_2O$ [1]

(iii) (dilution will) lower $E^{\ominus}$ for $Cr_2O_7^{2-}/Cr^{3+}$ *or* raise $E^{\ominus}$ for Cl_2/Cl^-
or lower $[Cl^-]$ *or* $[H^+]$ will shift equilibrium in eqn to the left hand side [1]

(iv) Br_2/Br^- = +1.07 V, so Cr(VI) would oxidise Br^- (easily) [1]
[6]
[Total: 9]

Q16.

5 (a) **2** MnO_4^- + **5** H_2O_2 + **6** $H^+ \longrightarrow$ **2** Mn^{2+} + **8** H_2O + **5** O_2 [1]
[1]

(b) $E^{\ominus}_{cell} = 1.52 - 0.68 = \mathbf{+0.84}$ (V) [1]
[1]

(c) (i) (as $KMnO_4$ is added), colour changed (from purple) to colourless – *NOT* pink
or effervescence/bubbles (of O_2) are produced [1]
at end-point, change is to (first) pink [1]

(ii) $n(MnO_4^-) = 0.02 \times 15/1000 = 3 \times 10^{-4}$ [1]
since $H_2O_2 : MnO_4^- = 5:2$,
$\Rightarrow n(H_2O_2) = (5/2) \times 3 \times 10^{-4} = 7.5 \times 10^{-4}$ in 25 cm^3
$\therefore [H_2O_2] = 7.5 \times 10^{-4} \times 1000/25 = \mathbf{3.0 \times 10^{-2}}$ mol dm^{-3} [1]
[4]
[Total: 6]

Q17.

1	**(a)**	CO_2 is a gas (at room temperature); SiO_2 is a high melting solid		[1]
		CO_2: simple / discrete molecular / covalent		[1]
		SiO_2: giant covalent *or* macromolecular / giant molecular		[1]
				[3]
	(b)	(a substance that is..) hard, high melting, electrical insulator	any two	[1]
		SiO_2 has **strong covalent** bonds (can be in **(a)**)		[1]
				[2]
	(c)	**(i)** amphoteric		[1]
		(ii) $2NaOH + PbO \longrightarrow Na_2PbO_2 + H_2O$		[1]
		(*or* $NaOH + PbO + H_2O \longrightarrow NaPb(OH)_3$ etc.)		
				[2]
	(d)	**(i)** $Zn + Sn^{4+} \longrightarrow Zn^{2+} + Sn^{2+}$		[1]
		(ii) $E^{\theta} = 0.15 - (-0.76) = \mathbf{0.91}$ V		[1]
		$E^{\theta} = 1.52 - 0.15 = \mathbf{1.37}$ V		[1]
		(iii) $n(Sn^{2+}) = 0.02 \times 13.5/1000 \times 5/2 = \mathbf{6.75 \times 10^{-4}}$ mol	use of the 5/2 ratio	[1]
			correct rest of working	[1]
		$n(Sn^{2+}) = 0.02 \times 20.3/1000 \times 5/2 = \mathbf{1.02 \times 10^{-3}}$ mol		[1]
		(iv) $n(Sn^{4+}) = 1.02 \times 10^{-3} - 6.75 \times 10^{-4} = 3.45 \times 10^{-4}$ mol		[1]
		$\therefore$ ratio $= 6.75/3.45 = 1.96:1 \approx \mathbf{2:1}$		
		$\therefore$ formula is $2SnO + SnO_2 \Rightarrow \mathbf{Sn_3O_4}$	*(cond^l on calculation, but allow ecf)*	[1]
				[8]
	(e)	**(i)** volume $= 1 \times 1 \times 1 \times 10^{-5} = 1 \times 10^{-5}$ m^3 *or* **10** cm^3		[1]
		(ii) mass = vol × density = 10 × 7.3 = **73** g	ecf	[1]
		moles = mass/A_r = 73/119 = **0.61** mol	ecf	[1]
		(iii) $Q = nFz = 0.61 \times 9.65 \times 10^4 \times 2 = \mathbf{1.18\ (1.2) \times 10^5}$ coulombs	ecf	[1]
				[4]

[Total: 19]

Q18.

8	**(a)**	Graphite / graphene	(1)
	(b)	They do not exist as sheets / layers of carbon atoms	(1)
	(c)	The lengths of nanotubes are much shorter than the curvature of the paper / they are so small that they are not effected by rolling	(1)
	(d)	Any molten ionic salt (or plausible organic ionic compounds)	(1)

[Total: 4]

Q19.

1 **(a)** $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$ (1)

$SiCl_4 + 2H_2O \rightarrow SiO_2 + 4HCl$ (or giving H_2SiO_3, $Si(OH)_4$ etc.) (1) **[2]**

(b) bond energies: S-S = 264 kJ mol^{-1}
Cl-Cl = 244 kJ mol^{-1}
S-Cl = 250 kJ mol^{-1}

$\Delta H = 8 \times 264 + 8 \times 244 - 16 \times 250 = +64$ kJ mol^{-1} (2) **[2]**

(c) **(i)** +2 (1)

(ii) (half) the sulfur goes up by +2, (1)
(the other half) goes down by –2 (1)

(iii) HCl (can be read into **(iv)**) (1)

(iv) $2SCl_2 + 2H_2O \rightarrow S + SO_2 + 4HCl$ (1)

(v) (+ $AgNO_3$) white ppt. (1)
(+ $K_2Cr_2O_7$) solution turns green (1) **[7]**

[Total: 11]

Q20.

3 **(a)** **(i)** $Cu(s) - 2e^- \rightarrow Cu^{2+}(aq)$ allow electrons on RHS (1)

(ii) $E^\ominus$ for Ag^+/Ag is +0.80V which is more positive than +0.34V for Cu^{2+}/Cu, (1) so it's less easily oxidised (owtte) (1)

(iii) $E^\ominus$ for Ni^{2+} is –0.25V, (1) Ni is readily oxidised and goes into solution as $Ni^{2+}(aq)$ (1) [Mark **(ii)** and **(iii)** to max 3]

(iv) $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ (1)

(v) $E^\ominus$ for Zn^{2+}/Zn is negative / = –0.76V, so Zn^{2+} is not easily reduced. (1)

(vi) The blue colour fades because $Cu^{2+}(aq)$ is being replaced by $Zn^{2+}(aq)$ *or* $Ni^{2+}(aq)$ *or* $[Cu^{2+}]$ decreases (1) **[7]**

(b) amount of copper = 225/63.5 = **3.54**(3) mol (1)
amount of electrons needed = 2 × 3.54 = **7.08/9** (7.087) mol (1)

no. of coulombs = 20 × 10 × 60 × 60 = 7.2×10^5 C
no. of moles of electrons = $7.2 \times 10^5 / 9.65 \times 10^4$ = **7.46** mol (1)

percentage "wasted" = 100 × (7.461 – 7.087)/7.461 = 5.01 (**5.0**)% (accept 4.98–5.10) (1) **[4]**

(c) $E^\ominus$ data: Ni^{2+}/Ni = –0.25V
Fe^{2+}/Fe = –0.44V (1)

Because the Fe potential is more negative than the Ni potential, the iron will dissolve (1) **[2]**

[Total: 13]

Q21.

9 **(a)** **(i)** A few nanometres (accept 0.5–10 nm) (1)

(ii) Graphite/graphene (1)

(iii) van der Waals' (1)
Carbon atoms in the nanotubes are joined by covalent bonds (1)
(as are the hydrogen atoms in a hydrogen molecule)
or no dipoles on C or H_2 *or* the substances are non-polar **[4]**

(b) More hydrogen can be packed into the same space/volume (1) **[1]**

(c) If a system at equilibrium is disturbed, the equilibrium moves in the direction which tends to reduce the disturbance (owtte) (1)

When H_2 is removed the pressure drops and more H_2 is released from that adsorbed (1)

The equilibrium $H_{2\,adsorbed} \rightleftharpoons H_{2\,gaseous}$ (1)

Equilibrium shifts to the right as pressure drops (1) **[4]**

[Total: 9]

Q22.

5 **(a)** **(i)** $2H_2O - 4e \rightarrow 4H^+ + O_2$ (1)

(ii) $2Cl^- - 2e \rightarrow Cl_2$ (1) **[2]**

(b) **(i)** E^o = (1.23 – (–0.83)) = <u>2.06V</u> (1)

(ii) E^o = (1.36 – (–0.83)) = <u>2.19V</u> (1)
(in **(i)** if **(a)(i)** as $4(OH^-) - 4e \rightarrow 2H_2O + O_2$ ecf is <u>0.4 – (–0.83) = 1.23</u> (1) – needs working shown) **[2]**

(c) **(i)** <u>no change</u> (because $[H_2O]$ does not change) (1)
smaller/less positive (1)

(ii) The (overall) <u>E^o for Cl_2 production will decrease</u>, (whereas that) for <u>O_2 production will stay the same</u>. (answer could be in terms of 1st E^o decreasing and becoming lower than 2nd)(or E^o for Cl_2 becomes less than for O_2) (1) **[3]**

(d) **(i)** $Cl^- + 3H_2O \rightarrow ClO_3^- + 3H_2$ (1)

(ii) n(C) = 250 × 60 × 60 = (**9 × 10^5** C) (1)
$n(e^-) = 9 \times 10^5/96500 = 9.33$ mol
$n(NaClO_3)$ = 9.33/6 = (**1.55** mol) – allow ecf (1)
$Mr(NaClO_3)$ = 106.5
mass $(NaClO_3)$ = 1.55 × 106.5 = **165.5** g (1) (165 – 166 gets 3 marks, 993 gets 2 marks as ecf) **[4]**

[Total: 11]

Q23.

1	(a)	$SiCl_4$: **white** solid *or* **white/steamy** fumes	[1]
		$SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$	[1]
		PCl_5: fizzes *or* white/steamy fumes	[1]
		$PCl_5 + 4H_2O \longrightarrow H_3PO_4 + 5HCl$	[1]
			[4]
	(b) (i)	$MnO_4^- + 8H^+ + 5Fe^{2+} \longrightarrow Mn^{2+} + 4H_2O + 5Fe^{3+}$	[1]
	(ii)	5 : 1	
	(iii)	$n(MnO_4^-) = 0.02 \times 15/1000 = 3 \times 10^{-4}$ (mol)	[1]
	(iv)	$n(Fe^{2+}) = 5 \times 3 \times 10^{-4} = 1.5 \times 10^{-3}$ (mol) ecf from **(i)** or **(ii)**	[1]
	(v)	$[Fe^{2+}] = 1.5 \times 10^{-3} \times 1000/2.5 =$ **0.6** (mol dm^{-3}) ecf from **(iv)**	[1]
	(vi)	In the original solution, there was 0.15 mol of Fe^{3+} in 100 cm^3. In the partially-used solution, there is 0.06 mol of Fe^{2+} in 100 cm^3.	
		So remaining Fe^{3+} = 0.15 – 0.06 = 0.09mol. ecf from **(v)**	[1]
		This can react with 0.045 mol of Cu, which = 0.045 × 63.5 = **2.86 g** of copper. ecf	[1]
			[6]
	(c)	bonds broken are Si-Si and Cl-Cl = 222 + 244 = 466 kJ mol^{-1} bonds formed are 2 × Si-Cl = 2 × 359 = 718 kJ mol^{-1} ΔH = **<u>–252</u>** kJ mol^{-1}	[2]
			[2]
	(d) (i)	$Ca_2Si + \mathbf{6}H_2O \longrightarrow \mathbf{2}Ca(OH)_2 + SiO_2 + \mathbf{4}H_2$	[1]
	(ii)	silcon has been oxidised **<u>AND</u>** hydrogen has been reduced	[1]
			[2]
			[Total: 14]

Q24.

2	(a)	(i)	**A** = $CuSO_4$	[1]
			B = silver	[1]
		(ii)	salt bridge	[1]
			voltmeter	[1]
				[4]
	(b)	(i)	0.80 – 0.34 = **(+) 0.46 V**	[1]
		(ii)	If E_{cell} = 0.17, this is 0.29 V less than the standard $E^{\ominus}$, so $E_{Ag\ electrode}$ must = 0.80 – 0.29 = **0.51 V**	[1]
		(iii)	0.51 = 0.80 + 0.06log [Ag^+], so [Ag^+] = $10^{(-0.29/0.06)}$ = **1.47 x 10^{-5}** mol dm^{-3} ecf from **(ii)**	[1]
				[3]
	(c)	(i)	$K_{sp} = [Ag^+]^2[SO_4^{2-}]$	[1]
			units = mol^3 dm^{-9} ecf on K_{sp}	[1]
		(ii)	$[SO_4^{2-}] = [Ag^+]/2$ $K_{sp} = (1.6 \times 10^{-2})^2 \times 0.8 \times 10^{-2}$ = **2.05 × 10^{-6}** (mol^3 dm^{-9})	[1]
				[3]
	(d)		AgCl white	[1]
			AgBr cream	[1]
			AgI yellow	[1]
			Solubility decreases down the group	[1]
				[4]
	(e)		solubility decreases down the group	[1]
			as M^{2+}/**ionic** radius increases	[1]
			both lattice energy **and** hydration (solvation) energy to decrease	[1]
			enthalpy change of solution becomes more endothermic	[1]
				[4]
				[Total: 18]

Q25.

1 (a) $MgCl_2$: forms a (colourless) solution **or** dissolves. [1]

$AlCl_3$: produces a white ppt **or** steamy fumes [1]

$2AlCl_3$ (**or** Al_2Cl_6) + $3H_2O \longrightarrow Al_2O_3 + 6HCl$ [1]
(**or** $AlCl_3 + 3H_2O \longrightarrow Al(OH)_3 + 3HCl$)

or forms a (colourless) solution **or** dissolves [1]

$AlCl_3 + 6H_2O \longrightarrow [Al(H_2O)_5(OH)]^{2+} + H^+ + 3Cl^-$ [1]

$SiCl_4$: produces a white ppt **or** steamy fumes [1]

$SiCl_4 + 2H_2O \longrightarrow SiO_2 + 4HCl$ [1]
(or balanced equation giving H_2SiO_3 **or** $Si(OH)_4$)

[Total: 5]

(b) (i) $n(NaCl) = 1.10/58.5 = 1.88 \times 10^{-2}$ mol [1]
$n(KCl) = 0.90/74.6 = 1.21 \times 10^{-2}$ mol [1]

total $n(Cl^-) = 3.08$ or 3.09 or 3.1×10^{-2} mol [2 or more sig. figs.] allow ecf

(ii) $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$ [1]

(iii) moles sampled for the titration $= 3.09 \times 10^{-2} \times 10/1000 = 3.09 \times 10^{-4}$ mol ecf [1]

this equals $n(Ag^+)$, so vol of $AgNO_3 = 3.09 \times 10^{-4} \times 1000/0.02 =$ **15.5** <u>cm</u>^{3} ecf [1]

[Total: 5]

(c) (i) bonds broken are C–H and I–I $= 410 + 151 = 561$ kJ mol^{-1} (all bonds = 5731 kJ mol^{-1})

bonds formed are C–I and H–I $=$ $240 + 299 = 539$ kJ mol^{-1} (all bonds = 5709 kJ mol^{-1})
$\Delta H =$ **+22** kJ mol^{-1} [2]

(ii) **4** HI + **2** $HNO_3 \longrightarrow$ **2** $I_2 + N_2O_3 +$ **3** H_2O (**or** double) [1]

N: (is reduced from) **5 to 3**
I: (is oxidised from) **–1 to 0** [1]

[Total: 4]

[TOTAL: 14]

Q26.

1 **(a)** P: burns with white / yellow flame *or* copious white smoke / fumes produced (1)

$4P \text{ (or } P_4) + 5O_2 \longrightarrow P_4O_{10}$ (1)

S: burns with blue flame / choking / pungent gas produced (1)

$S + O_2 \longrightarrow SO_2$ (1) [4]

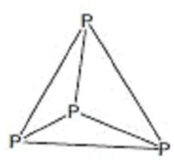
(b) **(i)** **2** $Ca_3(PO_4)_2$ + **6** SiO_2 + **10** C $\longrightarrow$ **1** P_4 + **6** $CaSiO_3$ + **10** CO (2)

(ii)

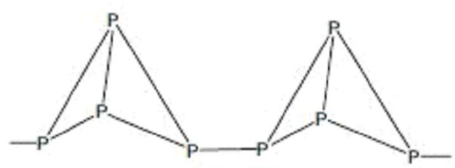
allotrope	type of structure	type of bonding
white	**simple / molecular**	**covalent**
red	**giant / polymeric**	**covalent**

(4)

(iii)



white P_4 (1)



red P_n (1)

(in each case P has to be trivalent. Many alternatives allowable for the polymeric red P) (2)

(8 max 7) [7]

[Total: 11]

Q27.

Q28.

4 (a) $N_2 + 2O_2 \rightarrow 2NO_2$ (*or* via NO) *or* $2NO + O_2 \rightarrow 2NO_2$ [1]

(b) (i) catalytic converter **and** passing the exhaust gases over a catalyst/Pt/Rh [1]

(ii) $NO_2 + 2CO \rightarrow \frac{1}{2} N_2 + 2CO_2$ ***or*** similar [1]
Allow $2NO_2 + CH_4 \rightarrow CO_2 + N_2 + 2H_2O$

(c) No, it wouldn't be reduced. Because the reaction in **(a)** does not presuppose a particular fuel (owtte) [1]
Allow formed from N_2 and O_2 in air during combustion

(d) (i) SO_3 produces acid rain [1]

(ii) $NO + \frac{1}{2} O_2 \rightarrow NO_2$ [1]

(iii) $K_p = (p_{NO} \cdot p_{SO_3})/(p_{NO2} \cdot p_{SO_2})$ [1]
units: dimensionless/none (don't accept just a blank!) [1]

(iv) $K_p = 99.8^2/0.2^2 = \mathbf{2.5 \times 10^5}$ [1]

(v) It will shift to the right (owtte) [1]
because the reaction is exothermic. NOT just Le Chatelier argument [1]

[Total: 11]

Q29.

4 (a) volatility: $Cl_2 > Br_2 > I_2$ *or* boiling points: $Cl_2 < Br_2 < I_2$ *or* Cl_2 is (g); Br_2 is (l); I_2 is (s) [1]
more electrons in X_2 down the group *or* more shells/bigger cloud of electrons [1]
so there's greater van der Waals/dispersion/id-id/induced/temporary dipole force/attraction [1]
[3]

(b) (i) $H_2O > H_2S$ *(see * below for mark)*
due to H-bonding in H_2O (none in H_2S) [1]
diagram minimum is: $H_2O^{\delta-} \cdots {}^{\delta+}H\text{-}OH$ *or* $H_2O{:}\cdot H\text{-}OH$ [allow (+) for $\delta+$] [1]

(ii) $CH_3\text{-}O\text{-}CH_3 > CH_3CH_2CH_3$ *(see * below for mark)*
due to dipole in $CH_3\text{-}O\text{-}CH_3$ (O is $\delta-$ not needed, but O is $\delta+$ negates) *or* CH_3OCH_3 is polar [1]
* correct comparison of boiling points for **both** [1]
[4]

(c) SF_6 has 6 bonding pairs/bonds and no lone pairs (bonds can be read into a diagram e.g. S-F, but 'no lone pairs' can *only* be read into a diagram showing 6 bonded pairs of electrons. [1]
clear diagram *or* 'shape is octahedral' [1]
[2]

[Total: 9]