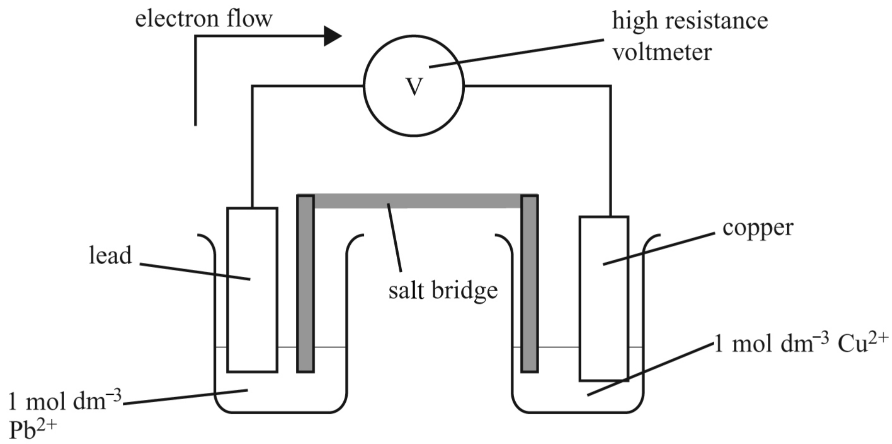
Chapter 20: Electrochemistry

Homework marking scheme

1 a i



voltmeter and salt bridge [1]
lead and copper [1]
1 mol dm^{-3} solutions or named solutions [1]
(Do not allow insoluble salts such as lead sulfate.)

ii completes circuit [1]
maintains ionic balance [1]

iii E_{cell} = +0.34 − (−0.13) V = 0.47 V [1]

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

v Arrow which shows the electrons moving from the lead to the copper. [1]

b In both parts of this question you have to show that changing the concentration of the ion changes the position of equilibrium and hence changes the number of electrons produced; this changes the electrode potential and hence the e.m.f. of the cell.

i The equilibrium at the lead electrode is $Pb(s) \rightleftharpoons Pb^{2+}(aq) + 2e^-$. [1]
If water is added to the solution, the concentration of lead ion decreases and therefore the equilibrium shifts to the right, making more electrons (Le Chatelier's principle). [1]
The electrode becomes more negative [1]
and the cell e.m.f. increases. [1]

ii The equilibrium at the copper electrode is $Cu(s) \rightleftharpoons Cu^{2+}(aq) + 2e^-$ [1]
If solid copper sulfate is added to the solution, the concentration of copper ions increases and the equilibrium shifts to the left in order to lower the concentration of copper ions. [1]
Therefore, the electrode becomes more positive as the number of electrons decreases. [1]
The e.m.f. of the cell increases. [1]

c i z is the number of electrons involved in the electrode reaction. [1]

ii $E = -0.13 + \frac{0.059}{2} \times \log_{10} 0.001$ [1]

$E = -0.13 + (-0.0885)$ V$= -0.219$ V [1]

iii $E = +0.34 + \frac{0.059}{2} \times \log_{10} 2.00$ [1]

$E = +0.34 + (+0.009)$ V $= +0.349$ V [1]

2 a If the lead(II) bromide is solid then the ions are not free to move [1]
and no current will flow. [1]
Note: the converse answer, i.e. if the lead bromide is molten then the ions are free to move and current will flow, will also get 2 marks.

b i At the negative electrode (the cathode) [1]

ii $Pb^{2+} + 2e^- \rightarrow Pb$ [1]

iii quantity of electricity passed in C = current × time = 0.4 × 2 × 60 × 60 = 2880 C [1]

quantity of electricity passed in F = $\frac{2880}{96500} = 2.98 \times 10^{-2}$ F [1]

1 mole of lead requires 2 F of electricity [1]

therefore, number of moles of lead deposited = ½ × $2.98 \times 10^{-2} = 1.49 \times 10^{-2}$ mol [1]

mass of lead deposited = $1.49 \times 10^{-2} \times 207.2 = 3.09$ g [1]

c i $2Br^- \rightarrow Br_2 + 2e^-$ [1]

ii This is oxidation because the bromide ions lose electrons *or* the oxidation number of the bromine has increased from −1 to 0. [1]

iii From the equation for the electrode reaction, 1 mol of bromine requires 2 F of electricity. [1]

Using the number of Faradays of electricity from part **b iii**, 1.49×10^{-2} mol of bromine are formed [1]

$PV = nRT$, $V = \frac{nRT}{P} = \frac{1.49 \times 10^{-2} \times 8.314 \times 700}{1.01 \times 10^{5}}$ m^3 [1]

$= 858$ cm^3 (using 1 $m^3 = 10^6$ m^3) [1]

d i The lead(II) chloride is an ionic compound. [1]

It has a high melting point. [1]

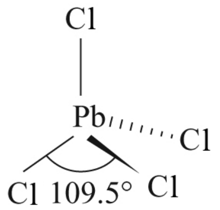
It conducts electricity when molten because in the liquid state the ions present can carry the current. [1]

ii Lead(IV) chloride is a simple molecular compound. [1]

It has a low melting point. [1]

It does not conduct electricity under any conditions because there are no charge-carrying particles present. [1]

iii



the three-dimensional representation of the molecule [1]

correct bond angle. [1]

3 **a** **i** A: hydrogen gas (at 1 atm pressure) [1]
B: salt bridge [1]
C: platinum electrode [1]
D: 1 mol dm^{-3} NaCl [1]
E: chlorine gas (at 1 atm pressure) [1]
the hydrogen and chlorine are both at 1 atm pressure. [1]
ii completes the circuit [1]
maintains an ionic balance [1]
iii filter paper soaked in [1]
saturated potassium nitrate solution [1]
b **i** $10Cl^- + 2MnO_4^- + 16H^+ \rightarrow 5Cl_2 + 2Mn^{2+} + 8H_2O$
correct reactants and products [1]
balancing. [1]
ii If Cl^- ions are diluted the equilibrium $Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$ moves to the right in order to correct the dilution (Le Chatelier's principle). [1]
This means that this half-cell reaction has a less negative electrode potential. [1]
If the H^+ ions are diluted the equilibrium
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$ moves to the left. [1]
This means that this half-cell reaction has a less positive electrode potential. [1]
The electrode potentials are such that the $Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-(aq)$ cannot proceed to the left and the $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l)$ reaction cannot proceed to the right. [1]
c **i** chlorine is oxidised from Cl_2 (oxidation number 0) to
ClO_3^- (oxidation number +5) [1]
chlorine is reduced from Cl_2 (oxidation number 0) to Cl^- (oxidation number −1) [1]
There is simultaneous oxidation and reduction in the same reaction (redox). [1]
ii sodium chlorate(V) [1]
number of moles of chlorine $= \frac{60}{24000} = 0.0025$ mol [1]
number of moles of $NaClO_3$ = ⅓ number of moles of chlorine $= \frac{0.0025}{3}$ [1]
mass of $NaClO_3 = n \times M_r = \frac{0.0025}{3} \times 106.6 = 0.089$ g [1]

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