REDOX AHL (HL only)

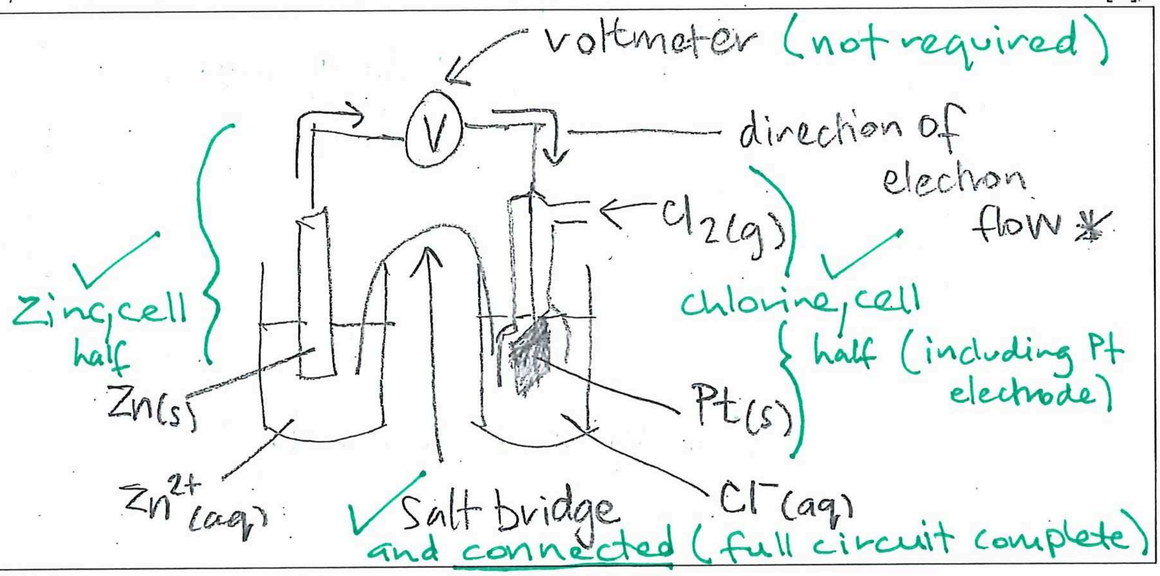
Please ensure that you have also completed the Core (SL & HL) questions

1. A voltaic cell is set up, cell notation below.

$Zn(s) \mid Zn^{2+}(aq) \parallel Cl^{-}(aq) \mid Cl_2(g) \mid Pt(s)$

(a) Draw a diagram of the voltaic cell. Label the components including the salt bridge.

[3]



(b) Mark arrows on the wires in the diagram above to show the direction of electron flow. ✱

arrows from Zn → Cl_2 half cells ✱ if electrons can flow.

[1]

(c) Write an equation for the overall cell reaction.

[1]

$Zn(s) + Cl_2(g) \longrightarrow Zn^{2+}(aq) + 2Cl^{-}(aq)$

state symbols not required

(d) Calculate the standard cell potential, in V, at 298K, using **section 24** of the data booklet.

[1]

chlorine +1.36

zinc −0.76

$E^{\ominus}_{cell} = +1.36 - -0.76$

$= +2.12$ (V)

(e) State the standard conditions under which the cell potential is measured.

[1]

298K, 100 kPa, Solutions of 1 $mol\,dm^{-3}$

all needed

(f) Calculate the standard free energy change, $\Delta G^\ominus$, for the cell using **sections 1 and 2** of the data booklet. Include units in your answer.

[3]

$\Delta G^\ominus = -nFE^\ominus$ $(F = 9.65 \times 10^4\ C\ mol^{-1})$

$= -2 \times 96500 \times 2.12$ ✓

$= -409160\ J$ } or ✓ + units ✓

$= -409\ kJ$

allow ecf.

(g) If the salt bridge is made of filter paper soaked in saturated potassium nitrate, $KNO_3(aq)$, describe the movement of the ions in the salt bridge when current is flowing.

[1]

NO_3^- / negative ions will flow from chlorine to zinc (half cells). K^+ / positive ions will flow from zinc to chlorine (half-cells). ✓ both ions needed.

2. The standard electrode potentials for three half-equations are given below:

$$Cf^{2+}(aq) + 2e^- \rightleftharpoons Cf(s) \quad E^\ominus = -2.12\ V$$

$$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq) \quad E^\ominus = +0.15\ V$$

$$Co^{3+}(aq) + e^- \rightleftharpoons Co^{2+}(aq) \quad E^\ominus = +1.82\ V$$

(a) Deduce which species from the half-equations above is the best reducing agent and explain why in terms of electrons.

[2]

Cf(s) / Californium or just Cf ✓ do not allow Cf^{2+}.

because it has the greatest tendency to lose electrons / Cf^{2+} has the least tendency to gain electrons. ✓

(b) Using the half-equations above, write an equation for the spontaneous cell reaction with the highest cell potential.

[2]

$Cf(s) + 2Co^{3+}(aq) \rightarrow Cf^{2+}(aq) + 2Co^{2+}(aq)$

Species correct ✓

state symbols not required. balanced ✓

(c) Calculate the cell potential for the reaction in (b).

[1]

$E^{\ominus}_{cell} = +1.82 - -2.12$

$= +3.94\,V$ ✓ (ignore units)

(d) Using **section 24** of the data booklet, identify a chemical species that could be used to oxidise $Co^{2+}(aq)$ ions. Explain your reasoning.

[2]

Fluorine / F_2 ✓

Fluorine half equation is more positive $E^{\ominus}$ /
Fluorine/F_2 is more likely to gain electrons ✓

2. A blue aqueous solution of copper sulfate, $CuSO_4(aq)$, can be electrolysed.

(a) Carbon electrodes are used in the electrolysis. Write half-equations for the reactions that would take place at the electrodes:

(i) Anode (positive electrode):

[1]

$H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$ ✓

(ii) Cathode (negative electrode):

[1]

$Cu^{2+} + 2e^- \rightarrow Cu$ ✓

(iii) State and explain whether or not the intensity of the colour of the solution will change as the electrolysis in (a) proceeds.

[1]

Yes, the blue colour will disappear / fade as Cu^{2+} ions are discharged. ✓

(b) The experiment is repeated using **copper** electrodes, instead of carbon.

(i) Write a half-equation for the reaction that would now take place at the anode.

[1]

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

state symbols not required

(ii) State and explain whether or not the intensity of the colour of the solution will change as the electrolysis proceeds in experiment (b).

[1]

✓ No, the colour will not change as copper 'lost' at cathode is 'replaced' from anode / concentration of Cu^{2+} ions remains constant.

(c) Calculate the mass of copper produced when a current of 2.0 A is passed through a concentrated solution of copper sulphate for 16 minutes and 20 seconds.

[4]

charge (C) = current (A) × time (s)

= 2.0 × 980 = 1960 C ✓

moles of electrons = $\frac{C}{F}$ = $\frac{1960}{96500}$ = 0.02031... ✓

($Cu^{2+} + 2e^- \rightarrow Cu$)

moles of copper = $\frac{0.02031...}{2}$ = 0.01015... ✓

mass of copper = 0.01015... × 63.55

= 0.64537...

= 0.65 g ✓

allow ecf.

Total Marks 27 (41 minutes)