Trinity College

Chemistry ATAR Unit 3+4

Electrochemical Cells Test

DO NOT MARK THIS PAPER

Total Marks = 51

1. Given these standard reduction potentials:

$E° = -0.28$ V for $Co^{2+}_{(aq)} + 2e^- \rightleftharpoons Co_{(s)}$
$E° = +0.34$ V for $Cu^{2+}_{(aq)} + 2e^- \rightleftharpoons Cu_{(s)}$

What is E° for $Co_{(s)} + Cu^{2+}_{(aq)} \rightleftharpoons Co^{2+}_{(aq)} + Cu_{(s)}$?

(a) +0.06 V
(b) +0.62 V
(c) +1.24 V
(d) Non spontaneous

2. Given the standard reduction potentials, which statement is correct?

$Cu^{2+}_{(aq)} + 2\,e^- \rightleftharpoons Cu_{(s)}$ E° = 0.34 V
$2H^+_{(aq)} + 2\,e^- \rightleftharpoons H_{2(g)}$ E° = 0.00 V
$Cr^{3+}_{(aq)} + 3\,e^- \rightleftharpoons Cr_{(s)}$ E° = –0.73 V

(a) $Cr_{(s)}$ will react with acid.
(b) $Cu_{(s)}$ will react with acid.
(c) $Cu^{2+}_{(aq)}$ will react with acid.
(d) $Cu_{(s)}$ will react with $Cr^{3+}_{(aq)}$.

Use the following information to answer questions 3-4.

A galvanic cell is constructed by placing a strip of zinc into a 1.0 mol L^{-1} solution of zinc nitrate and a strip of aluminum into a 1.0 mol L^{-1} solution of aluminum nitrate. The two metal strips are connected to a voltmeter by wires and a salt bridge connects the solutions. The temperature is 25 ^{0}C. The following standard reduction potentials apply:

$$Al^{3+}_{(aq)} + 3e^- \rightleftharpoons Al_{(s)} \qquad E^0 = -1.68\ V$$
$$Zn^{2+}_{(aq)} + 2e^- \rightleftharpoons Zn_{(s)} \qquad E^0 = -0.76\ V$$

3. What is E^0 for the cell described above?

(a) 2.43 V
(b) -2.43 V
(c) -0.92 V
(d) 0.92 V

4. In the cell described above, where does reduction occur?

(a) in the salt bridge
(b) in the aluminum nitrate solution
(c) at the zinc electrode
(d) at the aluminum electrode

5. Which of the following statements regarding a 'salt bridge' is **not** correct?

(a) A salt bridge allows ions to move between half-cells.
(b) A salt bridge prevents build up of charge in half-cells.
(c) A salt bridge allows electrons to move between half cells.
(d) A salt bridge takes no part in the chemical reaction occurring in either half-cell.

6. The Proton exchange membrane fuel cell which uses oxygen and hydrogen from the air is based on the spontaneous reaction that occurs when the following half-reactions are combined:

$$H_{2(g)} \rightarrow 2H^+_{(aq)} + 2e^- \qquad E^0 = 0\ V$$
$$O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightarrow 2H_2O_{(l)} \qquad E^0 = +1.23V$$

Which of the following statements regarding the oxygen-hydrogen fuel cell is true?

(a) The hydrogen electrode is the anode.
(b) The cell potential depends on pH.
(c) Oxidation occurs at the oxygen electrode.
(d) Electrons flow from the oxygen electrode to the hydrogen electrode.

7. Hydrogen peroxide can act as a reductant according to the half equation

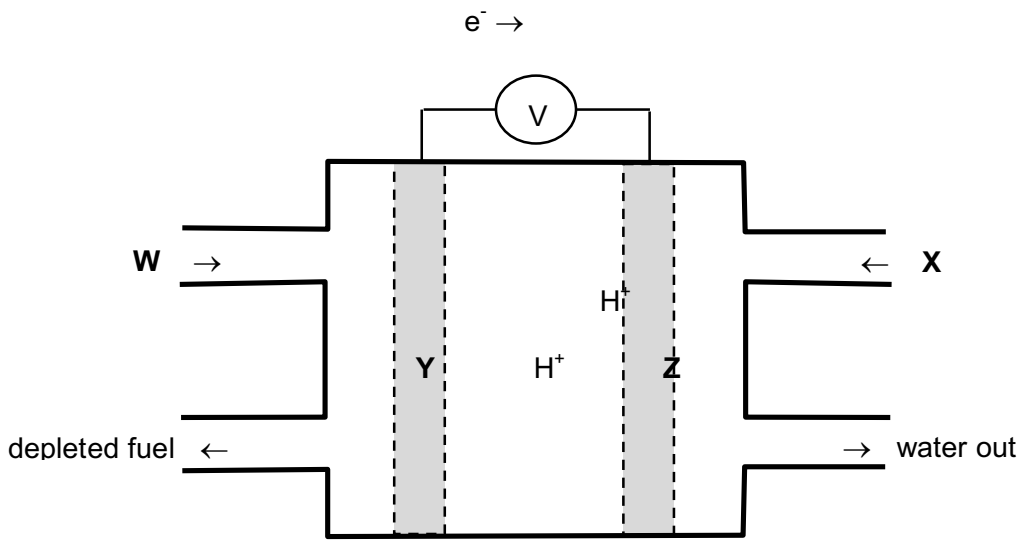
$$O_{2(g)} + 2H^+_{(aq)} + 2e^- \rightarrow H_2O_{2(aq)}; \qquad E^0 = +0.70\ V$$

Which of the following could all be reduced by hydrogen peroxide?

(a) $Fe^{2+}_{(aq)}$, $Cu_{(s)}$, $I^-_{(aq)}$
(b) $Ag^+_{(aq)}$, $Br_{2(aq)}$, $H_2O_{2(aq)}$
(c) $Ag_{(s)}$, $Br^-_{(aq)}$, $Fe^{2+}_{(aq)}$
(d) $I_{2(s)}$, $Cu^{2+}_{(aq)}$, $Fe^{3+}_{(aq)}$

Questions 8 and 9 refer to the information below.

The incomplete diagram below represents the phosphoric acid fuel cell (PAFC). As with other variations of the hydrogen / oxygen fuel cell, the only overall chemical product is water.



8. Which of the following **correctly** identifies the letters W, X, Y and Z in the diagram above?

	W	X	Y	Z
(a)	H_2	O_2	anode	cathode
(b)	O_2	H_2	anode	cathode
(c)	H_2	O_2	cathode	anode
(d)	O_2	H_2	cathode	anode

9. Which one of the following statements **BEST** describes the function of an anode in an electrolytic cell?

(a) The anode is the electrode at which reduction occurs.
(b) The anode is the only electrode at which OH^- (aq) ions are produced.
(c) The anode is the electrode which attracts positive ions.
(d) The anode is the electrode that is oxidised.

The overall redox reaction occurring in a dry cell, (Leclanché cell), is shown below.

$$Zn(s) + 2\,NH_4^+(aq) + 2\,MnO_2(s) \longrightarrow Zn^{2+}(aq) + Mn_2O_3(s) + H_2O(l) + 2NH_3(aq)$$

10. Which of the following statements regarding the dry cell are correct?

    I The zinc outer casing is acting as the anode.
    II The oxidation state of manganese decreases from +4 to +3.
    III Ammonium chloride acts as an electrolyte for the cell.

    (a) I and III only.
    (b) I and II only.
    (c) II and III only.
    (d) I, II and III.

11. "A non-rechargeable cell is constructed from a nickel oxyhydroxide cathode and an anode composed of an hydrogen-absorbing alloy. This cell has the ability to produce a voltage in the range of 1.4-1.6V."

    This description is consistent with a;

    (i) primary cell
    (ii) secondary cell
    (iii) electrolytic cell
    (iv) galvanic cell
    (v) fuel cell

    (a) (i) and (iii) only
    (b) (i) and (iv) only
    (c) (ii) and (iv) only
    (d) (i) and (v) only

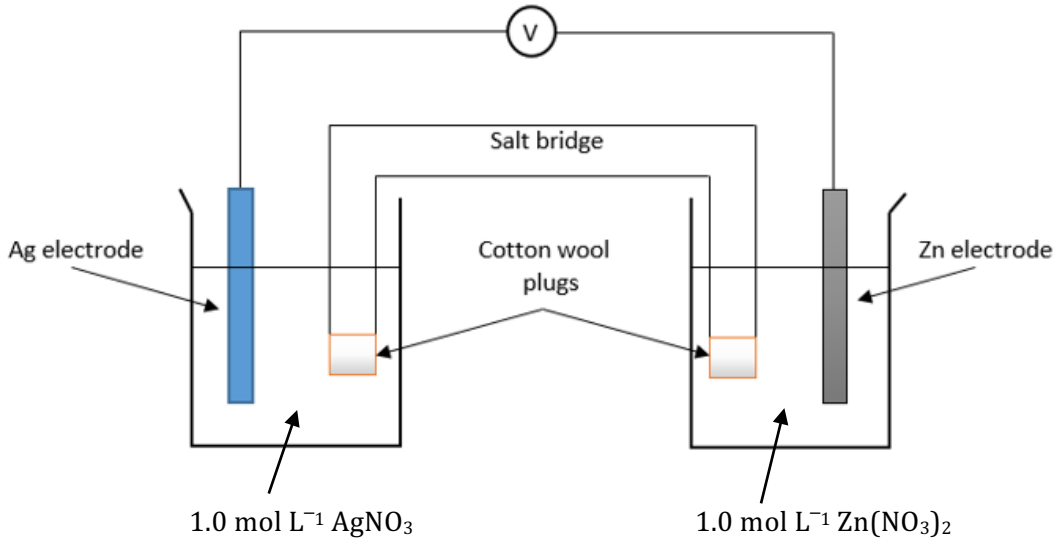
12. Consider the following statements about fuel cells.

    I A fuel cell converts chemical energy to electrical energy via a redox reaction.
    II Fuel cell technology involves the continuous supply of reactants to the cells and the continuous removal of the products.
    III A fuel cell can be recharged by reversing the direction of current flow through the cell.
    IV Fuel cells are considered a low-emission technology.

    Which of the above statements about fuel cells are true?

    (a) I only
    (b) I and II
    (c) I, III and IV
    (d) I, II and IV

Questions 13-15 relate to the following electrochemical cell at 25°C:



13. Which of the following reactions will occur during the normal operation of this cell?

(a)	$2Ag^+$ (aq)	+	Zn (s)	$\longrightarrow$	2Ag (s)	+	Zn^{2+} (aq)	$E^o = 1.56$ V
(b)	$2Ag^+$ (aq)	+	Zn (s)	$\longrightarrow$	2Ag (s)	+	Zn^{2+} (aq)	$E^o = 0.04$ V
(c)	Zn^{2+} (aq)	+	2Ag (s)	$\longrightarrow$	Zn (s)	+	$2Ag^+$ (aq)	$E^o = 1.56$ V
(d)	Zn^{2+} (aq)	+	2Ag (s)	$\longrightarrow$	Zn (s)	+	$2Ag^+$ (aq)	$E^o = 0.04$ V

14. Which of the following statements about the two electrodes is correct?

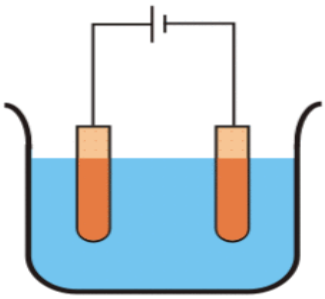
(a) The mass of the silver electrode will decrease.
(b) The zinc electrode is the cathode.
(c) The mass of the zinc electrode will decrease.
(d) The silver electrode is the anode.

15. Which of the following statements about the flow of charge is INCORRECT?

(a) Electrons will flow from the zinc electrode to the silver electrode through the external circuit.
(b) Cations will flow through the salt bridge towards the silver half-cell.
(c) Electrons will flow from the silver electrode to the zinc electrode through the salt bridge.
(d) Anions will flow through the salt bridge towards the zinc half-cell.

Short Answer (36 marks)

16. A 0.05 mol L^{-1} solution of $HCl_{(aq)}$ is to be electrolysed using inert electrodes as shown.



Determine the possible reactions at the anode and the cathode and give the overall reaction. Be sure to **include E^0 values.**

(6 marks)

17. Predict what reaction(s), if any, will occur when chlorine gas is bubbled through solutions of the following, and also any **observations**:

(Write a balanced equation for any reaction, and the **states**.)

(a) $NaI_{(aq)}$

(b) $H_2O_{2(aq)}$

[6 marks]

18. A tin rod dipping into a 1M $Sn(NO_3)_2$ and a cobalt rod dipping into 1M $CoSO_4$ solution are connected to a voltmeter (a salt bridge is included). Draw a large diagram of the circuit, indicating the flow of electrons, the anode and the cathode, the overall E° of the cell, the flow of ions across the salt bridge, the electrode that loses mass and the electrode gaining mass (if any).

Also write the overall equation for the cell.

[8 marks]

19. One of the many practical applications of electrochemical cell theory is in the construction of the lead-acid accumulator battery. A cell can be constructed from two lead plates, and a concentrated sulfuric acid solution. After the plates are added to the acid, a deposit forms on the surface of the lead plates. The cell is then charged electrolytically, and the deposit on the surface of the plates changes chemically. Once charged, the cell can be discharged, giving off a useable voltage. Use your standard reduction potential table to help you answer the following, **states required:**

(a) Give the anode half equation during DISCHARGE and the E^0.

(b) Give the cathode half equation during DISCHARGE and the E^0.

(c) Give the overall cell reaction.

(d) State the expected EMF of the cell.

(e) Car batteries are lead-acid accumulators; they have a voltage of 12V. How is this achieved in light of your answer to (d).

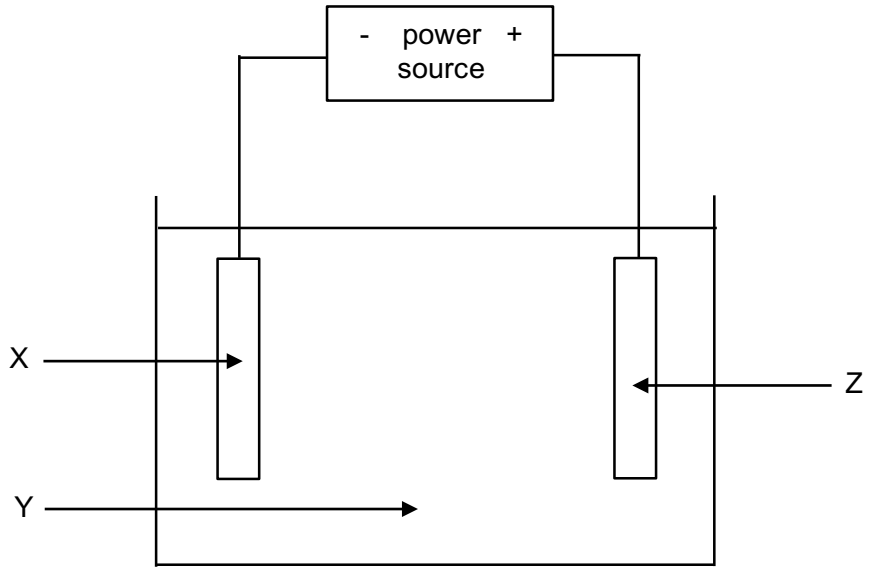
(f) Lead-acid accumulators are known as "secondary" cells. Why is this?

(g) List two advantages and disadvantages of a lead-acid battery.

[8 marks]

20.

The diagram below is a simplified, incomplete, representation of the final stage of copper purification, where the electrorefining of copper metal is carried out.



(a) Why is a power source required for this process? (2 marks)

(b) Give the name or formula of the substance that would be used for; (3 marks)

X _____

Y _____

Z _____

(c) Which letter denotes the cathode? (1 mark)

(d) Write the half equation for the reaction occurring at X. (1 mark)

(e) Why would $AgNO_3(aq)$ be an inappropriate substance to use for Y? (1 mark)

(8 marks)

END OF TEST