UNIT V- ELECTROCHEMISTRY STUDY GUIDE- *Written Questions*

SUGGESTIONS FOR USAGE:

- **Do as many types of questions as possible, paying attention to their differences as well as similarities**
- **Avoid "overuse" of keys…….do a question on your own, then compare against the answer key.**
- **The key provided is the actual key provided by the ministry of education….pay attention to how marks are awarded, and even more importantly how they are not awarded.**
- **Place an asterisk beside questions you got wrong or needed assistance on- DO THESE QUESTIONS AGAIN AT A LATER TIME!**
- **Use your INTENDED LEARNING OUTCOME SHEET to assist in your preparation for the final exam. The questions have been sequenced similarly to the way they are on your ILO sheet.**
- **Do not do the entire package in one session. Instead do one or two sections per day, concentrating on question types, ie sections in this document…**

INTRODUCTION

1. Consider the following equation:

$$2NO_2 \rightarrow N_2O_4$$

a) Does the above represent a redox reaction? ___________ **(0.5 marks)**
b) Explain **(1.5 marks)**

2. Define the term *oxidation-reduction reactio*n. **(2 marks)**

3. A series of experiments is performed to measure the E° produced by various combinations of metals in 1.00 M solutions of their salts.

Anode	Cathode	E°(V)
Be	Cd	1.297
Be	Ga	1.180
Ti	Be	0.050

Based on the data above,
a) list the metals in order of their activity (strongest reducing agent first). **(2 marks)**
b) predict the E ° of a Ti /Cd cell. **(1 mark)**

4. The metals A, B and C were separately placed in solutions containing the metallic ions A^{2+} ,B^{+} and C^{2+} . It was found that A reacted with B^{+} , but A did not react with C^{2+} .
a) Identify the strongest oxidizing agent. (1mark)
b) List the metals in order of increasing strength as reducing agents. (1mark)
c) Identify the ion(s) that will react with metal C. (1mark)

5. a) Indicate in the blank spaces on the following chart whether or not a reaction will occur when the metals are added to aqueous ions. **(1mark)**

ion \ metal	Pd	Rh	Pt
Pd^{2+}	X		
Rh^{2+}	no reaction	X	no reaction
Pt^{2+}	reaction	reaction	X

b) List the oxidizing agents in order of strongest to weakest. **(1mark)**

6. Consider the reaction:

$$2Fe^{3+}_{(aq)} + 2I^{-}_{(aq)} \rightarrow 2Fe^{2+}_{(aq)} + I_{2(aq)}$$

Is the reaction spontaneous? Explain. **(2 marks)**

7. A solution contains either acidified IO_3^- or acidified SO_4^{2-}. Why could the solution be identified using $I^-_{(aq)}$? Provide equations to support your answer. **(3 marks)**

BALANCING REDOX EQUATIONS

8. Balance the following half-reaction in basic solution. **(2 marks)**

$CNO^- \rightarrow CN^-$

9. Balance the following half-reaction in acidic conditions. **(2 marks)**

$Br_2 \rightarrow BrO_3^-$

10. Balance the following half-reaction: **(3marks)**

$Sb_2O_5 \rightleftarrows Sb_2O_3$ (basic)

11. Write the balanced equation for the half-reaction:

$Cu(OH)_2 \rightarrow Cu_2O$ (basic) **(3 marks)**

12. Balance the following half-reaction: **(3 marks)**

$CrO_4^{2-} \rightarrow Cr(OH)_3$ (basic)

13. Balance the following half-reaction: **(3 marks)**

$In_2O_3 \rightarrow In$ (basic)

14. Balance the following redox equation in an acidic solution. **(4 marks)**

$FeO_4^{2-} + NH_3 \longrightarrow N_2 + Fe^{3+}$

15. Balance the following redox reaction. **(3 marks)**

$Cu + NO_3^- \rightarrow Cu^{2+} + NO$ (in acid)

16. Balance the following equation. **(4 marks)**

$ClO_3^- + N_2H_4 \rightarrow NO + Cl^-$

17. Balance the following redox reaction occurring in an acidic solution. **(4marks)**

$As + ClO_3^- \rightarrow H_3AsO_3 + HClO$

18. Balance the following redox reaction: **(4 marks)**

$TcO_4^- + MnO_4^{2-} \rightarrow Tc + MnO_4^-$ (acidic)

19. a) Write the balanced equation for the redox reaction that occurs when $H_2S_{(g)}$ is bubbled into an acidified solution of $Cr_2O_7^{2-}$ (3 marks)
b) Calculate the E° for this reaction. (1mark)

20. Balance the following redox reaction in basic solution. **(3 marks)**

$$MnO_4^- + C_2O_4^{2-} \rightarrow MnO_2 + CO_2 \qquad \text{(basic)}$$

21. Balance the following redox reaction in acid:

$$N_2O_4 + In \rightarrow HNO_2 + In^{3+} \qquad \text{(acid)}$$ **(3 marks)**

22. Balance the following redox reaction in acidic solution:

$$RuO_4 + P \rightarrow Ru(OH)_2^{2+} + H_3PO_3 \qquad \text{(acid)}$$ **(3 marks)**

23. Balance the following redox reaction: **(3 marks)**

$$ClO_4^- + Al \rightarrow Cl^- + Al^{3+} \qquad \text{(acidic)}$$

24. Balance the following redox reaction: **(4 marks)**

$$Mn^{2+} + BiO_3^- \rightarrow MnO_4^- + Bi^{3+} \qquad \text{(acidic)}$$

25. Balance the following redox reaction: **(3 marks)**

$$Sb + HSO_4^- \rightarrow Sb_2O_3 + SO_2 \qquad \text{(acid)}$$

26. A redox reaction that occurs in an alkaline dry cell is:

$$Zn + 2MnO_2 \rightarrow Mn_2O_3 + ZnO \qquad \text{(basic)}$$

Write the balanced equation for the reduction half-reaction occurring in basic solution.**(3 marks)**

27. Balance the following redox reaction: **(3 marks)**

$$Ni + ClO_4^- \rightarrow Ni^{2+} + Cl^- \qquad \text{(acid)}$$

28. Balance the following redox reaction in **basic** solution: **(4 marks)**

$$Au + Cl^- + O_2 \rightarrow AuCl_4^- + OH^- \qquad \text{(basic)}$$

29. Balance the following redox reaction in a basic solution. **(4 marks)**

$$As \rightarrow AsH_3 + H_2AsO_4^- \qquad \text{(basic)}$$

30. In a titration, a 1.00 mL sample of an antiseptic solution containing hydrogen peroxide required 17.6 mL of a 0.0200 M solution of KMnO 4 to reach the endpoint. The equation for the reaction is

$$5H_2O_2 + 2MnO_4^- + 6H^+ \rightarrow 5O_2 + 2Mn^{2+} + 8H_2O$$

a) Identify the reducing agent. **(1 mark)**
b) Calculate the concentration of H_2O_2 in the antiseptic solution. **(3 marks)**

31. A technician tests the concentration of methanol, CH_3OH, in diluted windshield washer fluid using a redox titration. A 25.00 mL sample is titrated with 14.50 mL of 0.0200 M $KMnO_4$. Determine the concentration of methanol in the sample given the following redox reaction:

$$6H^+ + 2MnO_4^- + 5CH_3OH \rightarrow 5CH_2O + 2Mn^{2+} + 8H_2O$$

(3 marks)

32. An impure sample of iron was dissolved in acid. The Fe^{2+} in this solution was titrated with 0.0210 M $KMnO_4$. Use the following data table and redox equation to determine the moles of Fe^{2+} in the sample. **(3 marks)**

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

TRIAL	VOLUME $KMnO_4$
1	37.26 mL
2	35.18 mL
3	35.22 mL

33. Consider the following:

$$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

A 20.00 mL sample of a solution containing $[Fe^{2+}]$ was titrated using 0.0184 M $KMnO_4$ and the following data were collected.

	TRIAL 1	TRIAL 2	TRIAL 3
Volume of $KMnO_{4(aq)}$ used	29.07 mL	26.55 mL	26.45 mL

Calculate the concentration of Fe^{2+} in the solution. **(3 marks)**

34. The data below were obtained in a redox titration of a 25.00 mL sample containing Sn^{2+} ions using 0.125 M $KMnO_4$ according to the following reaction:

$$2MnO_4^- + 16H^+ + 5Sn^{2+} \rightarrow 2Mn^{2+} + 8H_2O + 5Sn^{4+}$$

	Volume of $KMnO_4$ used (mL)		
	Trial #1	Trial #2	Trial #3
Initial buret reading	2.00	13.80	24.55
Final buret reading	13.80	24.55	35.32

Calculate the $[Sn^{2+}]$ in the original sample. **(4 marks)**

35. Consider the following reaction:

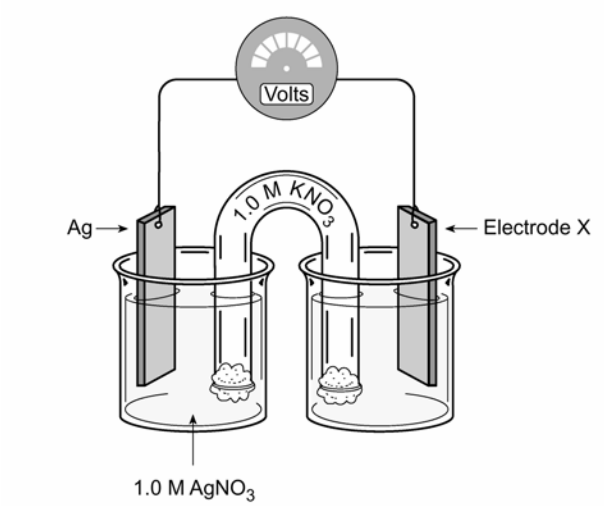
$$Cr_2O_7^{2-} + 6Br^- + 14H^+ \rightarrow 2Cr^{3+} + 3Br_2 + 7H_2O$$

In a redox titration, 15.58 mL of 0.125 M $Cr_2O_7^{2-}$ was needed to completely oxidize the Br^- in a 25.00 mL sample of NaBr. Calculate the $[Br^-]$ in the original solution.

(3 marks)

ELECTROCHEMICAL CELLS

36. **Consider the following electrochemical cell**:



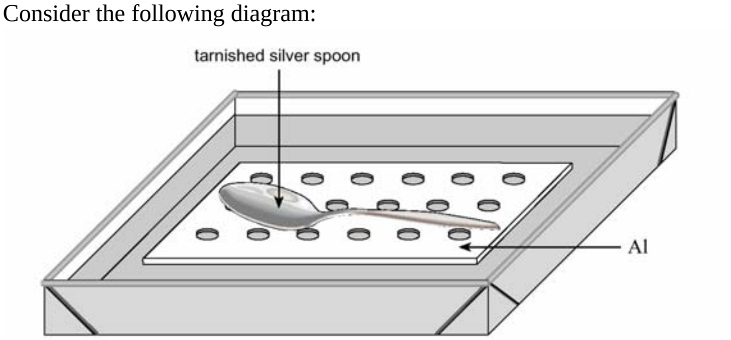
a) The initial cell voltage in the diagram above is 1.25 V. Identify electrode X.**(1 mark)**
b) Towards which electrode will the K + ions migrate? **(1 mark)**
c) Write the equation for the reduction half-reaction that occurs. **(1 mark)**
d) On the diagram, indicate the direction of electron flow. **(1 mark)**

37. The overall reaction in a fuel cell is:

$$2H_2 + O_2 \rightarrow 2H_2O$$

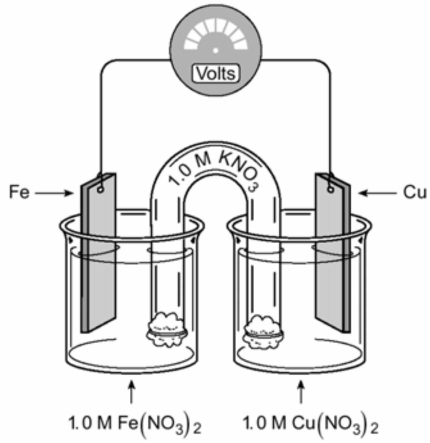
a) Write the equation for the half-reaction at the anode. **(1 mark)**
b) Is the overall reaction spontaneous? Explain. **(1 mark)**

38. Consider the following diagram:



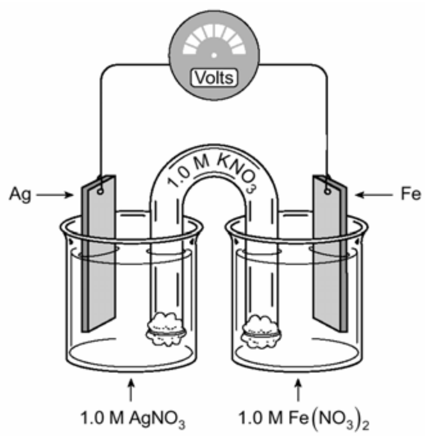
On a silver spoon, the black tarnish, Ag 2 S, can be removed spontaneously by placing the spoon in contact with aluminum in a conducting solution.
a) Write the equations for the two half-reactions. **(2marks)**
b) Write the equation for the redox reaction. **(1mark)**

39. Consider the following electrochemical cell:



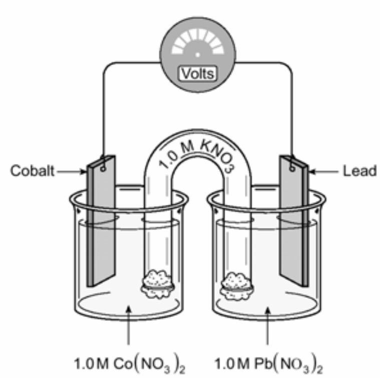
a) Clearly indicate on the diagram above, the direction of electron flow through the wire. **(1mark)**
b) Write the equation for the half-reaction taking place at the Fe electrode. **(1mark)**
c) What is the initial cell voltage? **(1mark)**

40. Consider the electrochemical cell:



a) Towards which half-cell do the $NO^{3-}_{(aq)}$ in the salt bridge initially move?**(1mark)**
b) Write the equation for the half-reaction occurring at the silver electrode. **(1mark)**
c) Identify the anode. **(1 mark)**
d) What is the initial cell voltage? **(1 mark)**

41. Consider the following electrochemical cell:

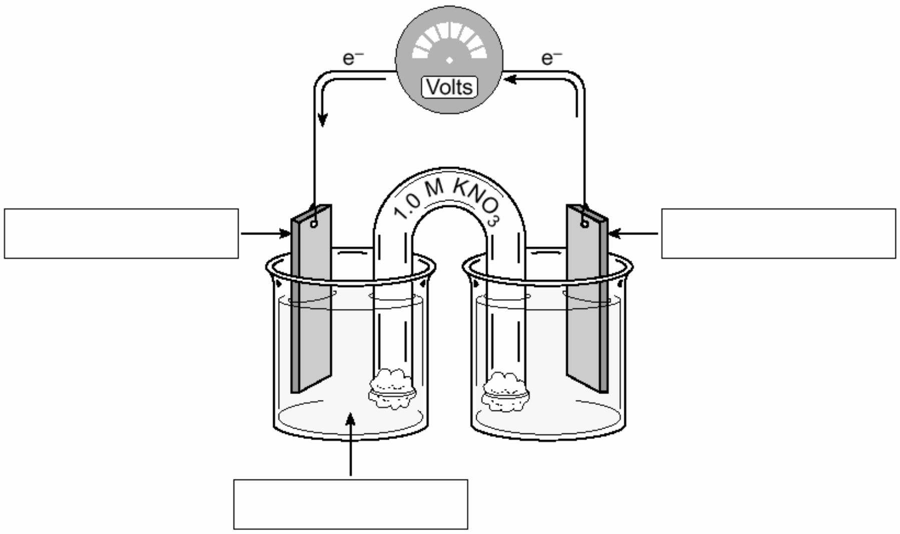


a) Calculate the initial cell voltage. **(1 mark)**
b) What is the purpose of the salt bridge? **(1 mark)**

42. l. Consider the following materials and cell diagram:

- silver, aluminum and nickel electrodes
- 1.0 M solutions of $AgNO_3$, $Al(NO_3)_3$ and $Ni(NO_3)_2$

a) From the above list, select the materials that are capable of producing the greatest voltage, then label the diagram below. **(3 marks)**



b) Calculate the initial voltage for the electrochemical cell in part a). **(1 mark)**
c) Which two metals from the above list would produce an electrochemical cell with the smallest initial voltage? **(1 mark)**

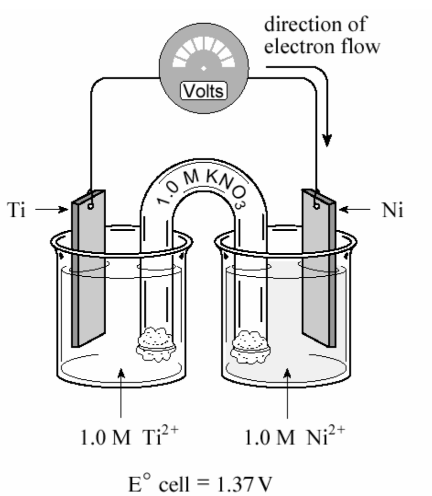
43.

Consider the following redox reaction:

$$H_2Se + SO_4^{2-} + 2H^+ \rightarrow Se + H_2SO_3 + H_2O$$

Calculate the $E°$ for the reaction above. **(2 marks)**

44.



Consider the following electrochemical cell:

a) Write the equation for the half-reaction that occurs at the anode. **(1 mark)**
b) Calculate the reduction potential of Ti^{2+} . **(1 mark)**

CORROSION

45. Describe **two** chemically different methods that can be used to prevent corrosion of iron and explain why each method works. **(2 marks)**

Method 1: ______________________________

____

Explanation: ______________________________

____

____

Method 2: ______________________________

____

Explanation: ______________________________

46. Consider the following reaction for the formation of rust:

$$Fe_{(s)} + \frac{1}{2}O_{2(g)} + H_2O_{(\ell)} \rightarrow Fe(OH)_{2(s)}$$

Describe and explain two methods, using different chemical principles, to prevent the formation of rust. **(2marks)**

47. a) Identify a metal that can be used to cathodically protect the iron hull of a ship. **(1 mark)**
b) Explain how the metal you chose prevents the iron from rusting. **(1 mark)**

ELECTROLYTIC CELLS

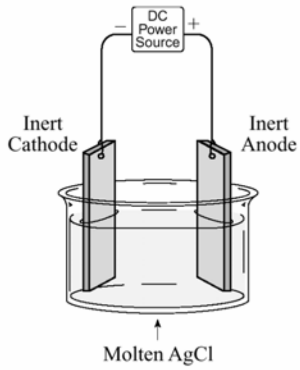
48. What is an *electrolytic cell*? **(2 marks)**

49. Define the term *electrolysis*. **(2marks)**

50. Draw and label a simple electrolytic cell capable of electroplating an inert electrode with silver. **(2marks)**

51. In the electrolysis of 1.0 M LiF, the products are oxygen gas and hydrogen gas.
a) Write the anode half-reaction and include the E° value. **(1 mark)**
b) Write the cathode half-reaction and include the E° value. **(1 mark)**
c) Calculate the minimum voltage required for this electrolysis. **(1 mark)**

52. Consider the following electrolytic cell used for the electrolysis of molten AgCl.



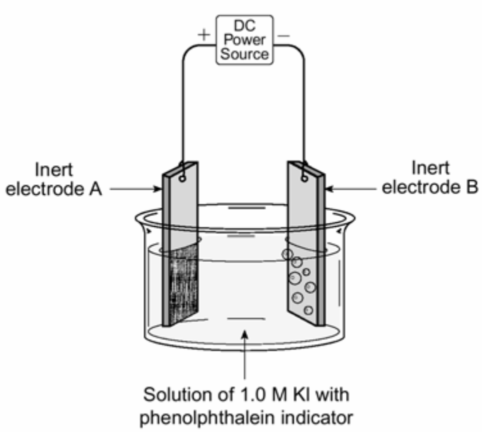
a) Clearly indicate on the diagram above, the direction of the electron flow through the wire. **(1 mark)**
b) Write the equation for the half-reaction taking place at the anode. **(1 mark)**
c) Write the equation for the half-reaction taking place at the cathode. **(1 mark)**
d) Write the equation for the overall reaction. **(1mark)**

53. Consider the electrolysis of 1.0 M H_2SO_4 using inert platinum electrodes.

a) Write the oxidation half-reaction. **(1 mark)**

b) Write the reduction half-reaction. **(1 mark)**

54. Consider the following cell used for the electrolysis of 1.0 M KI solution containing a few drops of phenolphthalein indicator.



a) Write the equation for the half-reaction taking place at electrode A. **(1 mark)**
b) As the cell operates, gas bubbles form and the solution turns pink around electrode B. **(2 marks)**
i) Identify the gas that forms.
ii) Explain why the solution turns pink.

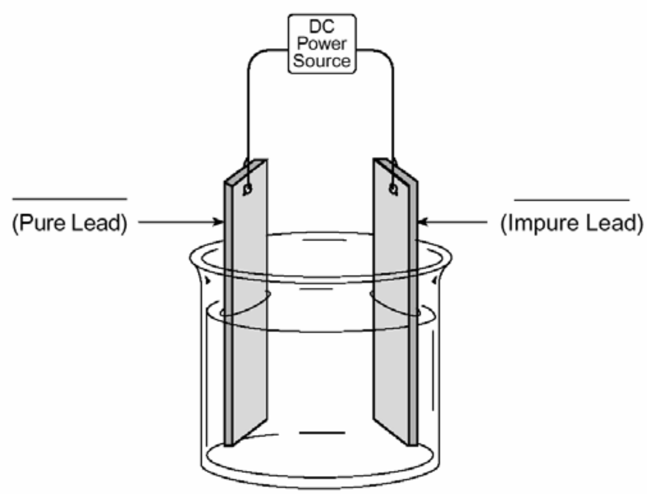
55. An electrolytic cell can be used to plate a copper penny with a silver coating. Sketch a diagram of the electrolytic cell. Label the cathode and show the direction of electron flow. **(2 marks)**

56. A trophy manufacturer electroplates an iron trophy with gold.

a) Write the equation for the half-reaction that occurs at the iron trophy. **(1 mark)**
b) Identify an appropriate electrolyte. **(1 mark)**
c) Identify the cathode. **(1 mark)**
d) Explain how to maintain a constant metal ion concentration in the electrolyte.**(1 mark)**

57. A student wishes to electroplate a coin with copper.
a) Identify a suitable anode. **(1 mark)**
b) Identify an appropriate electrolyte. **(1 mark)**
c) To which battery terminal (positive or negative) should the coin be connected?
(1 mark)

58. Consider the following diagram for the electrorefining of lead:

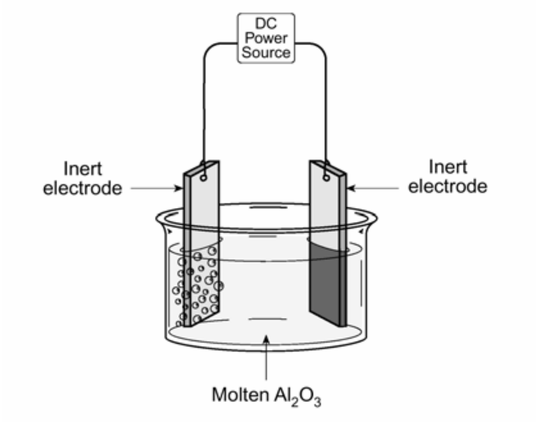


a) On the diagram above, label the anode and the cathode. **(1 mark)**
b) Write the formula for a suitable electrolyte. **(1 mark)**
c) Write the equation for the reduction half-reaction. **(1 mark)**

59. In an electrolytic cell, current is passed through molten NaCl.
a) Suggest suitable electrodes for this process. **(1 mark)**
b) Write the equation for the reaction occurring at the cathode. **(1 mark)**
c) Write the **overall** equation. **(1 mark)**

60. Consider the electrolysis of **molten** magnesium chloride.
a) Identify the product formed at the anode. **(1 mark)**
b) Write the equation for the reduction half-reaction. **(1 mark)**
c) Write the equation for the overall reaction. **(1 mark)**

61. **Consider the following electrolytic cell used for the electrolysis of molten aluminum oxide**.



a) Write the equation for the half-reaction taking place at the anode. **(1 mark)**
b) Write the equation for the half-reaction taking place at the cathode. **(1 mark)**
c) Clearly indicate on the diagram above, the direction of electron flow. **(1 mark)**

SOLUTION KEY:

1.	a) No, the reaction is not redox b) The oxidation number of nitrogen in NO 2 and in N 2 O 4 is + 4. With no change in the oxidation number there is no loss or gain of electrons.
2.	**For example:** A chemical reaction in which electrons are transferred from one chemical species to another chemical species. **{2 marks}**
3.	a) Ti>Bi>Ga>Cd b) 1.347V
4.	a) B^+ b) B,A,C c) B^+ and A^{2+}
5.	(table below) b) $Pt^{2+}>Pd^{2+}>Rh^{2+}$

ion \ metal	Pd	Rh	Pt
Pd^{2+}		***reaction***	***no reaction***
Rh^{2+}	no reaction		no reaction
Pt^{2+}	reaction	reaction	

b) $Pt^{2+}>Pd^{2+}>Rh^{2+}$

6. Yes, the reaction is spontaneous as can be seen by the fact that Fe^{3+} (oxidizing agent) is further up on the reduction chart than is I^- (reducing agent) giving rise to a $+E^0$ value.

7. I^- reacts with acidified IO_3^- but not with acidified SO_4^{2-}. ← **1 mark**

$$2\times\left(IO_3^- + 6H^+ + 5e \rightarrow \tfrac{1}{2}I_2 + 3H_2O\right)$$
$$5\times\left(2I^- \rightarrow I_2 + 2e^-\right)$$
$$2IO_3^- + 12H^+ + 10I^- \rightarrow 6I_2 + 6H_2O$$
$$IO_3^- + 6H^+ + 5I^- \rightarrow 3I_2 + 3H_2O$$
← **2 marks**

8. $$2H^+ + CNO^- + 2e^- \longrightarrow CN^- + H_2O$$

9. $Br_2 + 6H_2O \rightarrow 2BrO_3^- + 12H^+ + 10e^-$ ← **2 marks**

One-half mark for each step: balancing bromine
balancing oxygen
balancing hydrogen
balancing charge

10. $Sb_2O_5 + 4H^+ + 4e^- \rightleftarrows Sb_2O_3 + 2H_2O$ ← **2 marks**

$Sb_2O_5 + 2H_2O + 4e^- \rightleftarrows Sb_2O_3 + 4OH^-$ ← **1 mark**

11.

$$2Cu(OH)_2 + 2e^- \rightarrow Cu_2O + H_2O + 2OH^-$$

Balanced in acid $\leftarrow$ **2 marks**

Convert to base $\leftarrow$ **1 mark**

12.

Balance O $\leftarrow \frac{1}{2}$ **mark**

Balance H $\leftarrow \frac{1}{2}$ **mark**

Balance charge $\leftarrow$ **1 mark**

$$\left.\begin{array}{ll} CrO_4^{2-} + 5H^+ + 3e^- \rightarrow Cr(OH)_3 + H_2O & \text{(acid)} \\ CrO_4^{2-} + 4H_2O + 3e^- \rightarrow Cr(OH)_3 + 5OH^- & \text{(base)} \end{array}\right\} \leftarrow \textbf{1 mark}$$

13.

$$\left.\begin{array}{l} In_2O_3 + 6H^+ + 6e^- \rightarrow 2In + 3H_2O \\ In_2O_3 + 3H_2O + 6e^- \rightarrow 2In + 6OH^- \end{array}\right\} \leftarrow \textbf{3 marks}$$

14.

For **each** balanced half-reaction.

$8H^+ + FeO_4^{2-} + 3e^- \rightarrow Fe^{3+} + 4H_2O \leftarrow$ **1 mark**

$2NH_3 \rightarrow N_2 + 6H^+ + 6e^- \leftarrow$ **1 mark**

For multiplying top equation by 2× $\leftarrow$ **1 mark**

For adding and cancelling electrons and H^+ $\leftarrow$ **1 mark**

$$2FeO_4^{2-} + 10H^+ + 2NH_3 \rightarrow 2Fe^{3+} + 8H_2O + N_2$$

15.

$3(Cu \rightarrow Cu^{2+} + 2e^-)$ $\leftarrow \frac{1}{2}$ **mark** for each half-reaction

$2(NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O)$ $\leftarrow$ **1 mark** for balancing electrons

$3Cu + 2NO_3^- + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$ $\leftarrow$ **1 mark**

16.

$4(ClO_3^- + 6H^+ + 6e^- \rightarrow Cl^- + 3H_2O)$ $\leftarrow$ **1 mark** for each half-reaction

$3(N_2H_4 + 2H_2O \rightarrow 2NO + 8H^+ + 8e^-)$ $\leftarrow$ **1 mark** for balancing electrons

$4ClO_3^- + 3N_2H_4 \rightarrow 4Cl^- + 6NO + 6H_2O$ $\leftarrow$ **1 mark**

17.

Half-cell Method:

1 mark (for multiplying both half-reactions)

$4(As + 3H_2O \rightarrow H_3AsO_3 + 3H^+ + 3e^-)$ $\leftarrow$ **1 mark**

$3(ClO_3^- + 5H^+ + 4e^- \rightarrow HClO + 2H_2O)$ $\leftarrow$ **1 mark**

$4As + 6H_2O + 3ClO_3^- + 3H^+ \rightarrow 4H_3AsO_3 + 3HClO$ $\leftarrow$ **1 mark**

18.

$$TcO_4^- + 8H^+ + 7e^- \rightarrow Tc + 4H_2O$$ ← **1 mark** for each half-reaction

$$\left(MnO_4^{2-} \rightarrow MnO_4^- + e^-\right) \times 7$$ ← **1 mark** for ×7

$$TcO_4^- + 7MnO_4^{2-} + 8H^+ \rightarrow Tc + 7MnO_4^- + 4H_2O$$ ← **1 mark** for addition

19.

$$\left(Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftarrows 2Cr^{3+} + 7H_2O\right)$$ ← **½ mark**

1 mark → $$3\left(H_2S \rightleftarrows S + 2H^+ + 2e^-\right)$$ ← **½ mark**

for balancing electrons

$$Cr_2O_7^{2-} + 3H_2S + 8H^+ \rightarrow 2Cr^{3+} + 3S + 7H_2O$$ ← **1 mark**

b) +1. 09 V

20.

$$2 \times \left(2H_2O + 3e^- + MnO_4^- \rightarrow MnO_2 + 4OH^-\right)$$
$$3 \times \left(C_2O_4^{2-} \rightarrow 2CO_2 + 2e^-\right)$$
} **2 marks**

$$4H_2O + 2MnO_4^- + 3C_2O_4^{2-} \rightarrow 6CO_2 + 2MnO_2 + 8OH^-$$ ← **1 mark**

21.

$$3 \times \left(N_2O_4 + 2H^+ + 2e^- \rightarrow 2HNO_2\right)$$ ← **1½ marks for half reactions**

$$2 \times \left(In \rightarrow In^{3+} + 3e^-\right)$$ ← **½ mark for balancing electrons**

$$3N_2O_4 + 6H^+ + 2In \rightarrow 6HNO_2 + 2In^{3+}$$ ← **1 mark**

22.

$$3 \times \left(RuO_4 + 6H^+ + 4e^- \rightarrow Ru(OH)_2^{2+} + 2H_2O\right)$$
$$4 \times \left(P + 3H_2O \rightarrow H_3PO_3 + 3H^+ + 3e^-\right)$$
} **1 mark for reactions**
1 mark for balancing electrons

$$3RuO_4 + 6H^+ + 6H_2O + 4P \rightarrow 3Ru(OH)_2^{2+} + 4H_3PO_3$$ } **1 mark for addition and simplification**

23.

1 mark → $$3\ \left(ClO_4^- + 8H^+ + 8e^- \rightarrow Cl^- + 4H_2O\right)$$ ← **½ mark**

1 mark → $$8\ \left(Al \rightarrow Al^{3+} + 3e^-\right)$$ ← **½ mark**

$$3ClO_4^- + 8Al + 24H^+ \rightarrow 3Cl^- + 8Al^{3+} + 12H_2O$$ ← **1 mark**

24.

1 mark → $$5\ \left(BiO_3^- + 6H^+ + 2e^- \rightarrow Bi^{3+} + 3H_2O\right)$$ ← **1 mark**

1 mark → $$2\ \left(Mn^{2+} + 4H_2O \rightarrow MnO_4^- + 8H^+ + 5e^-\right)$$ ← **1 mark**

$$5BiO_3^- + 2Mn^{2+} + 14H^+ \rightarrow 5Bi^{3+} + 2MnO_4^- + 7H_2O$$ ← **1 mark**

25.

1 mark for e^- balance →

$$2Sb + 3H_2O \rightarrow Sb_2O_3 + 6H^+ + 6e^-$$ ← **½ mark**

$$3 \times \left(HSO_4^- + 3H^+ + 2e^- \rightarrow SO_2 + 2H_2O\right)$$ ← **½ mark**

$$2Sb + 3HSO_4^- + 3H^+ \rightarrow Sb_2O_3 + 3SO_2 + 3H_2O$$ ← **1 mark**

26.

$$2MnO_2 + 2H^+ + 2e^- \rightarrow Mn_2O_3 + H_2O$$ ← **2 marks in acid**

$$2MnO_2 + H_2O + 2e^- \rightarrow Mn_2O_3 + 2OH^-$$ ← **1 mark for changing to basic**

27. 1 mark for e^- balance

$$4\times(Ni \rightarrow Ni^{2+} + 2e^-) \quad \leftarrow \tfrac{1}{2}\text{ mark}$$
$$1\times(8e^- + 8H^+ + ClO_4^- \rightarrow Cl^- + 4H_2O) \quad \leftarrow \tfrac{1}{2}\text{ mark}$$
$$4Ni + 8H^+ + ClO_4^- \rightarrow 4Ni^{2+} + Cl^- + 4H_2O \quad \leftarrow 1\text{ mark}$$

28.

$$4\times(Au + 4Cl^- \rightarrow AuCl_4^- + 3e^-)$$
$$3\times(4e^- + 3H^+ + O_2 \rightarrow OH^- + H_2O)$$
$$4Au + 16Cl^- + 9H^+ + 3O_2 \rightarrow 4AuCl_4^- + 3OH^- + 3H_2O$$
$$+9OH^- \qquad +9OH^-$$
$$4Au + 16Cl^- + 6H_2O + 3O_2 \rightarrow 4AuCl_4^- + 12OH^-$$

1 mark for half-reactions
1 mark for balancing charges
1 mark for addition
1 mark for basic

29.

$$5\times(3e^- + 3H^+ + As \rightarrow AsH_3) \quad \leftarrow \text{1 mark for half-reactions}$$
$$3\times(4H_2O + As \rightarrow H_2AsO_4^- + 6H^+ + 5e^-) \quad \leftarrow \text{1 mark for balancing electrons}$$
$$12H_2O + 8As \rightarrow 5AsH_3 + 3H_2AsO_4^- + 3H^+ \quad \leftarrow \text{1 mark for addition, cancellation}$$

BASIC Add $3OH^-$ to each side.

$$9H_2O + 3OH^- + 8As \rightarrow 5AsH_3 + 3H_2AsO_4^- \quad \leftarrow \text{1 mark for basic}$$

30. a) H_2O_2
b)

$$\text{mol } MnO_4^- = 0.0200\text{ M} \times 0.0176\text{ L} = 0.000352\text{ mol} \quad \leftarrow \text{1 mark}$$
$$\text{mol } H_2O_2 = 0.000352\text{ mol } MnO_4^- \times 5\text{ mol } H_2O_2 / 2\text{ mol } MnO_4^- = 0.000880\text{ mol} \quad \leftarrow \text{1 mark}$$
$$[H_2O_2] = \frac{0.000880\text{ mol}}{0.00100\text{ L}} = 0.880\text{ M} \quad \leftarrow \text{1 mark}$$

31.

$$\text{Moles of } KMnO_4 = 0.01450\text{ L} \times 0.0200\text{ mol/L} = 2.90\times10^{-4}\text{ mol} \quad \leftarrow \text{1 mark}$$
$$\text{Moles of } CH_3OH = \frac{5(2.90\times10^{-4}\text{ mol})}{2} = 7.25\times10^{-4}\text{ mol} \quad \leftarrow \text{1 mark}$$
$$[CH_3OH] = 7.25\times10^{-4}\text{ mol}/0.0250\text{ L} = 0.0290\text{ M} \quad \leftarrow \text{1 mark}$$

NOTE: ($\tfrac{1}{2}$ mark) is deducted for incorrect significant figures.

32.

$$\text{Average volume } KMnO_4 = 35.20\text{ mL} \quad \leftarrow \text{1 mark}$$
$$\text{mol } KMnO_4 = (0.03520\text{ L})(0.0210\text{ M}) = 7.392\times10^{-4}\text{ mol} \quad \leftarrow \text{1 mark}$$
$$\text{mol } Fe^{2+} = \left(\frac{5\text{ mol } Fe^{2+}}{1\text{ mol } MnO_4^-}\right)(7.39\times10^{-4}\text{ mol}) = 3.70\times10^{-3}\text{ mol} \quad \leftarrow \text{1 mark}$$

$\tfrac{1}{2}$ mark was deducted for incorrect significant figures

33. Volume of $KMnO_4$ = 26.50 mL ← **1 mark**

$$\text{mol } MnO_4^- = 0.0184 \text{ M} \times 0.02650 \text{ L} = 4.876\times10^{-4} \text{ mol}$$
$$\text{mol } Fe^{2+} = 5\times 4.876\times10^{-4} \text{ mol}$$
$$= 2.438\times10^{-3} \text{ mol}$$
$$[Fe^{2+}] = \frac{2.438\times10^{-3} \text{ mol}}{0.02000 \text{ L}}$$
$$= 0.122 \text{ M}$$

← **2 marks**

34. Average volume of $KMnO_4$ in Trials 2 and 3 = 0.01076 L ← **1 mark**

Moles of $KMnO_4 = (0.125\,\text{M})(0.01076\,\text{L}) = 1.345\times10^{-3}$ mol ← **1 mark**

Moles of $Sn^{2+} = \frac{5}{2}(1.345\times10^{-3}\text{ mol}) = 3.363\times10^{-3}$ mol ← **1 mark**

Molarity of $Sn^{2+} = \frac{(3.363\times10^{-3}\text{ mol})}{0.025\,\text{L}} = 0.134\,\text{M}$ ← **1 mark**

(Deduct $\frac{1}{2}$ **mark** for incorrect significant figures.)

35. mol $Cr_2O_7^{2-} = (0.01558 \text{ L})(0.125 \text{ M}) = 1.9475\times10^{-3}$ mol $Cr_2O_7^{2-}$ ← **1 mark**

$$\text{mol } Br^- = (1.9475\times10^{-3} \text{ mol } Cr_2O_7^{2-})\left(\frac{6 \text{ mol } Br^-}{1 \text{ mol } Cr_2O_7^{2-}}\right)$$

$= 1.1685\times10^{-2}$ mol Br^- ← **1 mark**

$$[Br^-] = \frac{1.1685\times10^{-2} \text{ mol } Br^-}{0.02500 \text{ L}}$$

$= 4.67\times10^{-1}$ M ← **1 mark**

Note: ($\frac{1}{2}$ mark deduction for incorrect significant figures.)

36. a) Iron b) towards the Ag electrode

c)

$$Ag^+_{(aq)} + e^- \rightleftarrows Ag_{(s)}$$

d) Electrons flow from electrode X to the silver electrode.

37. a)

$$H_{2(g)} + 2OH^- \rightarrow 2H_2O + 2e^-$$ ← **1 mark**

b)

Yes, the reaction is spontaneous.

For example:

- $0.82 - (-0.41) = 1.23$ V
- Positive E° value
- Electrochemical cell

38. a)

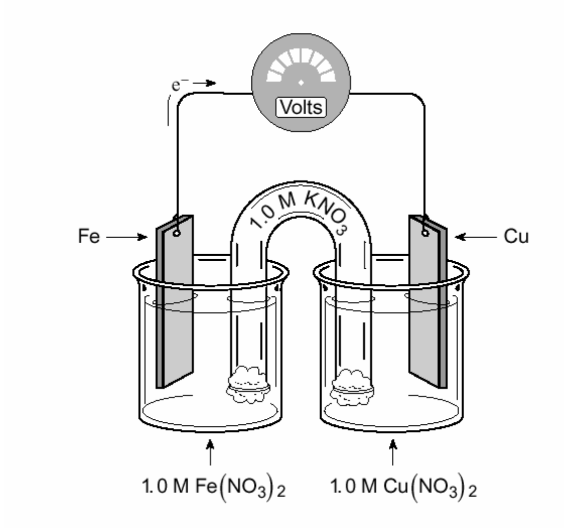
$Ag_2S + 2e^- \rightarrow 2Ag + S^{2-}$ ← **1 mark**

$Al \rightarrow Al^{3+} + 3e^-$ ← **1 mark**

b)

$3Ag_2S + 2Al \rightarrow 6Ag + 2Al^{3+} + 3S^{2-}$ } ← **1 mark**

39.



b)

$Fe \rightarrow Fe^{2+} + 2e^-$ ← **1 mark**

c)

$$\begin{array}{r} 0.45\ V \\ +0.34\ V \\ \hline +0.79\ V \end{array}$$ ← **1 mark**

40. a) Towards Fe cell **or** Towards right

b)

$$Ag^+ + e^- \rightarrow Ag$$

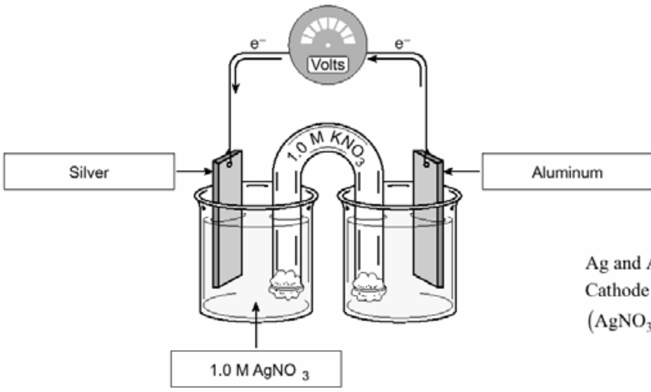
c) $Fe_{(s)}$

d)1.25v

41. a) 0.15 Volts

b)The salt bridge allows ion migration in order to equalize the charge.

42.



Ag and Al: ← **1 mark**
Cathode (Ag): ← **1 mark**
$(AgNO_3)$ ← **1 mark**

b) Initial cell voltage = 0.80 + 1. 66 = 2. 46 V **{1 mark}**
c) Ag and Ni **{1mark}**

43.

$$H_2Se \rightarrow Se + 2H^+ + 2e^- \qquad E° = +0.40\ V \qquad \leftarrow \textbf{1 mark}$$

$$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O \qquad E° = +0.17\ V \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

$$E° = +0.57\ V \qquad \leftarrow \tfrac{1}{2}\ \textbf{mark}$$

44. a)

$$Ti \rightarrow Ti^{2+} + 2e^- \qquad \leftarrow \textbf{1 mark}$$

b)

$$E°_{(for\ cell)} = E°_{(for\ reduction)} + E°_{(for\ oxidation)}$$

$$Ni^{2+} + 2e^- \rightarrow Ni$$

$$E°_{(for\ reduction)} = -0.26\,V$$

$$1.37\,V = (-0.26\,V) + E°_{(for\ oxidation)}$$

$$E°_{(for\ oxidation)} = 1.63\,V$$

Therefore, the reduction potential of Ti^{2+} is $-1.63\,V$ ← **1 mark**

45. ***For Example:***

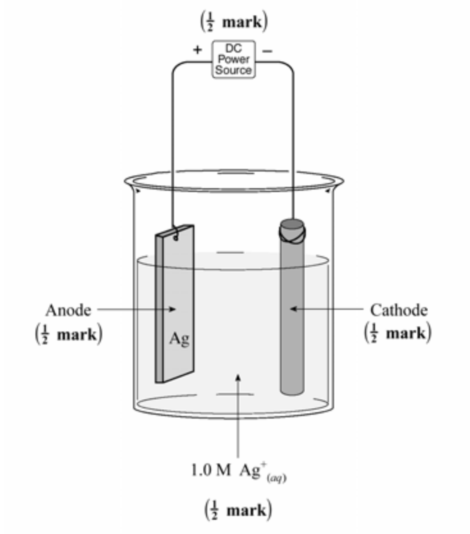
(Any **two** of the following for **2 marks**. $\frac{1}{2}$ **mark** for each method, $\frac{1}{2}$ **mark** for each explanation.)

- paint the iron — prevents collision of O_2 and H_2O molecules with iron so that rust cannot form
- attach a material such as magnesium — provides cathodic protection (i.e., it is more readily oxidized than the iron)
- provide a small current through the iron object (e.g., boat hull) — prevents or reverses the reaction forming rust

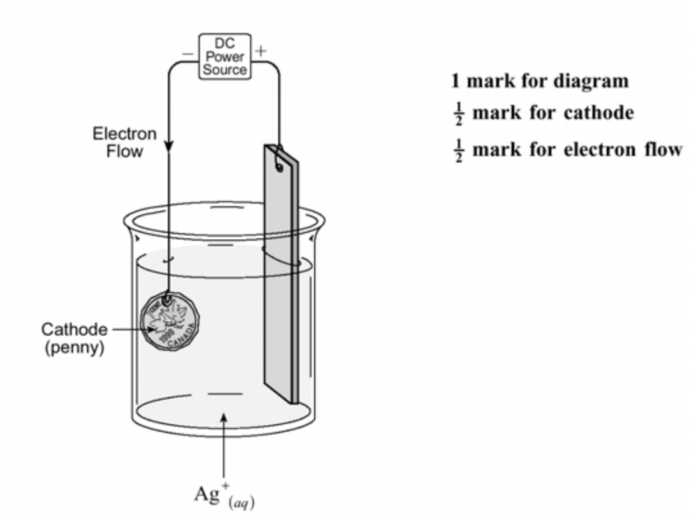
46. Coating with zinc $\left(\frac{1}{2}\ \textbf{mark}\right)$. Zinc acts as a sacrificial anode $\left(\frac{1}{2}\ \textbf{mark}\right)$.
Painting $\left(\frac{1}{2}\ \textbf{mark}\right)$ prevents contact between Fe and O_2 $\left(\frac{1}{2}\ \textbf{mark}\right)$.

47. a) Mg or Zn (for example)
b) Attaching a more active metal causes the iron to become a cathode by supplying it with electrons.

48. A cell which depends on an external source of electricity to cause a non-spontaneous redox reaction to occur.**{2marks}**

49.	**For example:** The process of applying an electric current to cause a chemical reaction to occur. {**2 marks}**
50.	
51.	a) $H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^- \quad -0.82\ V$ b) $2H_2O + 2e^- \rightleftarrows H_2 + 2OH^-\left(10^{-7}\ M\right) \quad -0.41\ V$ c) Minimum voltage is >1.23 volts.
52.	a) Electron flow is from the anode to the cathode on the diagram. b) $2Cl^- \rightarrow Cl_2 + 2e^-$ c) $Ag^+ + e^- \rightarrow Ag$ d) $2Ag^+ + 2Cl^- \rightarrow 2Ag + Cl_2$
53.	$H_2O \rightarrow \frac{1}{2}O_2 + 2H^+ + 2e^-$ ← **1 mark** b) $2H^+ + 2e^- \rightarrow H_2$ ←
54.	a) $2I^- \rightarrow I_2 + 2e^-$ ← **1 mark** b) Hydrogen gas. 1 mark c) The pink colour is due to the production of the hydroxide ion. 1 mark

55.



56. a)

$$Au^{3+}_{(aq)} + 3e^- \rightarrow Au_{(s)} \quad \leftarrow \textbf{1 mark}$$

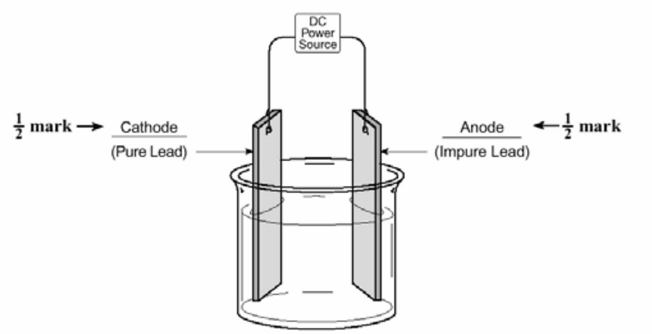
b) $Au(NO_3)_3$ (for example) c) Iron Trophy d) Use a gold anode or add $Au(NO_3)_3$

57. a) **For example:** Copper metal or Cu , Carbon or C , Platinum or Pt

b) Copper(II) nitrate or $Cu(NO_3)_2$, Copper(II) chloride or $CuCl_2$, Copper(II) sulphate or $CuSO_4$

c) To the negative terminal.

58.



a) For Example $Pb(NO_3)_2$

b) $Pb^{2+} + 2e^- \rightarrow Pb$

59. a) Pt or carbon or other inert electrodes

b)

$$Na^+ + e^- \rightarrow Na \quad \leftarrow \textbf{1 mark}$$

c)

$$2NaCl \rightarrow 2Na + Cl_2 \quad \leftarrow \textbf{1 mark}$$

60. a) Chlorine gas or Cl_2

b)

$$Mg^{2+} + 2e^- \rightarrow Mg$$

c)

$$MgCl_{2(l)} \rightarrow Mg_{(l)} + Cl_{2(g)}$$

or

$$Mg^{2+}_{(l)} + 2Cl^-_{(l)} \rightarrow Mg_{(l)} + Cl_{2(g)}$$

61. a)

$$2O^{2-} \rightarrow O_2 + 4e^- \qquad \leftarrow \textbf{1 mark}$$

b)

$$Al^{3+} + 3e^- \rightarrow Al \qquad \leftarrow \textbf{1 mark}$$

c) Electrons flow from left to right through the wire. **1 mark**
-see diagram to the right