CHEMISTRY 3A/3B

Solutions to

MAJOR TEST 4

CHAPTERS 9, 10

TIME ALLOWED 60 minutes

<u>This test is made up of two sections</u>

Section 1 contains 19 multiple choice questions worth 19 marks

Section 2 contains 6 questions worth 38 marks

Section 1 :

The following information refers to items 1 and 2:

The button cells used in hearing aids, watches and cameras is often the alkaline silver oxide/zinc cells. When these cells are in operation the cell potential is 1.5 V and the overall cell reaction occurring is:

$$Ag_2O_{(s)} + Zn_{(s)} + H_2O_{(l)} \longrightarrow 2Ag_{(s)} + Zn(OH)_{2(s)}$$

1. In the reaction above the change in oxidation number of the silver is:

   A +1 to 0

   B -1 to 0

   C +2 to +1

   D +2 to 0

   E 0 to +1

2. In this button cell, zinc forms

   A the cathode and is reduced

   B the positive electrode and is oxidized

   C the negative electrode and is reduced

   D the negative electrode and is oxidized

3. The oxidation number of chromium in the compound, potassium chromate, K_2CrO_4 is:

   A 7

   B 6

   C 4

   D -2

4. Which one of the following species (atom or ion) would you expect to be the strongest oxidant ?

   A Br^-

   B Ag^+

   C Pb^{2+}

   D Mg

4. Consider the following information:

$Ce^{4+}(aq) + e \longrightarrow Ce^{3+}(aq)$ $\quad E^o = 1.44$ V

$Sn^{4+}(aq)\ 2e \longrightarrow Sn^{2+}(aq)$ $\quad E^o = 0.15$ V

$X^+(aq) + e \longrightarrow X(s)$ $\quad E^o = E_x$

If metal X(s) is oxidised to $X^+(aq)$ by 1 mol L^{-1} solutions of $Ce^{4+}(aq)$ and $Sn^{4+}(aq)$, but not by 1 mol L^{-1} $H^+(aq)$ solution, the value of E_x must be :

A less than zero volts

B between zero volts and 0.15 V

C between 0.15 V and 1.44 V

D greater than 1.44 V

5. As current is drawn from a lead-acid accumulator the battery can be described as discharging. During this discharging process the pH of the electrolyte solution of the battery

A decreases steadily

B increases steadily

C remains constant

D initially decreases, then remains constant

6. Using your table of E^o values predict which metals below could successfully reduce a 1 mol L^{-1} solution of nickel sulfate

A silver and copper metals

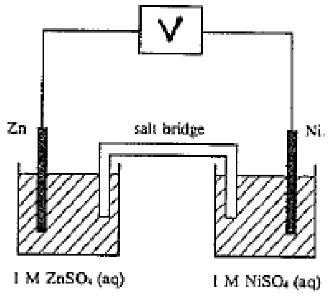
B copper and iron metals

C silver, copper, iron and zinc metals

D zinc and iron metals

Answers:
4 B
5 B
6 D

Questions 7 and 8 refer to the following cell as represented below:



7. The cell potential would be expected to be:

   A 1.01 V

   B 0.76 V

   C 0.51 V

   D 0.25 V

8. As current flows through the cell

   A the zinc electrode loses mass and negative ions move towards the nickel electrode via the salt bridge

   B the zinc electrode gains mass and would be described as the anode

   C the nickel electrode gains mass and would be the negatively charged electrode

   D the nickel electrode gains mass and negative ions move towards the zinc electrode through the salt bridge

Answers:
7. C
8. D

12. Galvanising is a more effective technique of corrosion control than is tin plating, especially when the surface is scratched. Which one of the following statements gives the BEST reason for this ?

A tin is more reactive than zinc

B zinc is more reactive than iron

C tin is more reactive than iron

D zinc is less reactive than iron

E zinc is harder than tin

13. The following statements relate to the standard hydrogen half-cell. Which statement is FALSE ?

A It uses a platinum electrode

B It is assigned a reduction potential of 1.00 V

C It involves the reduction of hydrogen ions or the oxidation of hydrogen gas

D It uses hydrogen gas with a pressure of 101.3 kPa

E It contains hydrogen ions with a concentration of 1.0 mol L^{-1}

Answers:
12. B
13. B

4. The standard reduction potentials for the gain of one electron by the ions $Cu^{+}(aq)$ and $Cu^{2+}(aq)$ are as follows:

$$Cu^{+}(aq) + e \rightleftharpoons Cu(s) \qquad E^{o} = 0.52\ V$$
$$Cu^{2+}(aq) + e \rightleftharpoons Cu^{+}(aq) \qquad E^{o} = 0.15\ V$$

The standard potential for the disproportionation reaction

$2Cu^{+}(aq) \longrightarrow Cu^{2+}(aq) + Cu(s)$, is :

A - 0.67 V

B + 0.37 V

C - 0.37 V

D + 0.67 V

E + 0.87 V

5. 20 mL of a 0.1 mol L^{-1} solution of metal ions reacted completely with 20 mL of a 0.1 mol L^{-1} sulfur dioxide solution. The sulfur dioxide reacts according to the equation:

$$SO_2(aq) + 2H_2O(l) \longrightarrow SO_4^{2-}(aq) + 4H^{+}(aq) + 2e$$

If the original oxidation number of the metal ions was + 3 , their oxidation number after the reaction would be:

A +1

B +2

C 0

D +4

E +5

6. Which one of the following is NOT an oxidation -reduction reaction ?

A $Mg + 2H^{+} \longrightarrow Mg^{2+} + H_2$

B $2C + O_2 \longrightarrow 2CO$

C $2Ag^{+} + Cu \longrightarrow 2Ag + Cu^{2+}$

D $Ag^{+} + I^{-} \longrightarrow AgI$

E $Cl_2 + 2I^{-} \longrightarrow 2Cl^{-} + I_2$

Answers:

4. B

5. A

6. D

7. For the reaction:

$2MnO_4^- + 10Br^- + 16H^+ \longrightarrow 2Mn^{2+} + 5Br_2 + 8H_2O$

which one of the following statements is true ?

A the permanganate ion is reduced and the hydrogen is oxidised

B the hydrogen ion is reduced and the bromide ion is oxidised

C the permanganate ion is reduced and the bromide ion is oxidised

D the permanganate is the reducing agent and the bromide is the oxidising agent

E the permanganate is the reducing agent and the hydrogen ion is the oxidising agent

8. Chlorine dioxide, Cl_2O , oxidises iodide ion according to the following unbalanced equation:

$ClO_2 + I^- + H^+ \longrightarrow Cl^- + I_2 + H_2O$

How many moles of iodine would be produced by the reaction of two moles of ClO_2 ?

A 1

B 2

C 3

D 4

E 5

9. Which one of the following half equations best represents the reaction that takes place at the electrode where electrons enter the cell from the external circuit when a dry cell is being discharged ?

A $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e$

B $2MnO_2(s) + 2NH_4^+(aq) + 2e \longrightarrow Mn_2O_3(s) + 2NH_3(aq) + H_2O(l)$

C $PbO_2(s) + HSO_4^-(aq) + 3H^+(aq) + 2e \longrightarrow PbSO_4(s) + 2H_2O(l)$

D $Zn^{2+}(aq) + 2e \longrightarrow Zn(s)$

E $Mn_2O_3 + 2OH^-(aq) \longrightarrow 2MnO_2(s) + H_2O(l) + 2e$

Answers:

7. C

8. E

9. B

11. Which one of the following is the strongest reducing agent ?

A silicon

B calcium

C chlorine

D aluminium

E potassium permanganate

12. Consider the following standard reduction potentials:

$$Pb^{2+} + 2e \rightleftharpoons Pb \qquad -0.13\ V$$
$$Ni^{2+} + 2e \rightleftharpoons Ni \qquad -0.25\ V$$
$$Fe^{2+} + 2e \rightleftharpoons Fe \qquad -0.44\ V$$

If three beakers were prepared containing:

I Fe(s) in nickel nitrate solution

II Pb(s) in nickel nitrate sloution

III Ni(s) in nickel nitrate solution, then reaction could occur in:

A I, II and III

B II and III only

C I and III only

D I only

E II only

Answers:

11. B

12. D

SECTION 2: ANSWER THESE QUESTIONS IN THE SPACES PROVIDED.

1. Balance the following equation by first writing the relevant half-equations:

$$U^{4+}(aq) + MnO_4^-(aq) + H_2O(l) \longrightarrow MnO_2(s) + UO_2^+(aq) + H^+(aq)$$

$3U^{4+} + \cancel{2}6H_2O \rightarrow 3UO_2^+ + \cancel{4}12H^+ + 3e^-$ [1]

$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$ [1]

$3U^{4+} + MnO_4^- + 4H_2O \rightarrow 3UO_2^+ + MnO_2 + 8H^+$ [2]

(4 marks)

2. Metals X, Y and Z and ions of these metals are known to undergo the following reactions:

$Y^{2+} + 2e \rightleftharpoons Y$

$X^{2+} + 2e \rightleftharpoons X$

$Z^{2+} + 2e \rightleftharpoons Z$

$Z(s) + X^{2+}(aq) \rightarrow Z^{2+}(aq) + X(s)$

$X(s) + Y^{2+}(aq) \rightarrow X^{2+}(aq) + Y(s)$

$Z(s) + Y^{2+}(aq) \rightarrow Z^{2+}(aq) + Y(s)$

List the metals in order of increasing reductant strength.

Y X Z

(3 marks)

3. An electrochemical cell is constructed using two half cells. One half consists of an inert platinum electrode and a solution of Fe^{2+} and Fe^{3+}. The other half cell consists of a lead electrode and a solution of Pb^{2+}.

Current will flow from one electrode to the other electrode when the cell is completed using a voltmeter and a salt bridge.

(a) Write relevant half- equations and a balanced net ionic equation for the overall cell reaction.

$2Fe^{3+} + 2e^- \rightarrow 2Fe^{2+}$ [1]

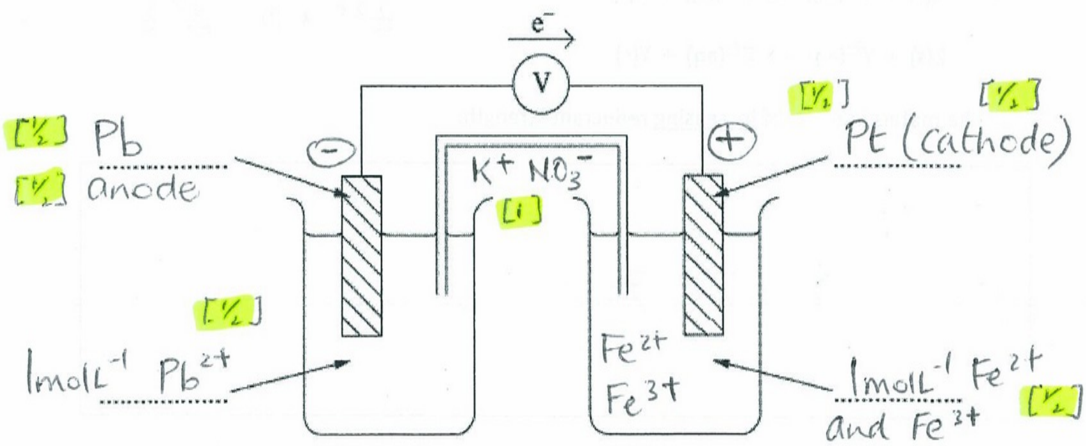
$Pb \rightarrow Pb^{2+} + 2e^-$ [1]

$2Fe^{3+} + Pb \rightarrow Pb^{2+} + 2Fe^{2+}$ [1]

(b) Calculate the standard cell potential (E°).

$0.77 - (-0.13) = 0.90V$ [1]

(c) Identify the anode, cathode, metals and ions by labelling the following diagram.



(d) Identify an appropriate electrolyte to use in the salt bridge. Write it on the diagram above.

(3 + 1 + 3 + 1 marks)

4. The button cell present in the watch you are wearing is most likely to be made from silver oxide and zinc. The cell reaction occurring is best expressed as:

$$Zn(s) + Ag_2O(s) + H_2O(l) \longrightarrow 2Ag(s) + Zn^{2+}(aq) + 2OH^-(aq)$$

The cell potential of one of these cells is 1.50 V

(a) Write the half-equations for the reactions occurring at the anode and cathode. Label each one.

~~(b)~~

Zn [½]

[1] $Zn \rightarrow Zn^{2+} + 2e^-$ Oxidation (ANODE)

[1] $Ag_2O + 2e^- + H_2O \rightarrow 2Ag + 2OH^-$ reduction (CATHODE)

Ag_2O [½]

(c) Name the oxidant and reductant in the cell

Ag_2O oxidant [½]

Zn reductant [½]

(d) From the information provided in the question and your E° table determine the standard reduction potential for the half-cell containing $Ag_2O(s)$.

$Ag_2O/2Ag$ must be 1.50 V greater than Zn^{2+}/Zn (−0.76)

$\Rightarrow E^\circ(Ag_2O/Ag) = 0.74$ V [2]

(3 + 1 + 2 marks)

$\underbrace{2H^+ + 2OH^-}_{2H_2O} + Ag_2O \rightarrow 2Ag + \cancel{H_2O} + 2OH^-$

5. A lead-acid accumulator or car battery produces a steady voltage of 12V when it is being discharged. The battery is made up of six cells connected in series and each contains a lead electrode and a lead (IV) oxide electrode in a 4 mol L^{-1} sulfuric acid solution.

(a) Using your data sheet, write the two half-cell reactions occurring and label them the reduction half-equation and the oxidation half-equation.

$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$

$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_{4(s)} + 2H_2O$ [1]

$Pb + SO_4^{2-} \rightarrow PbSO_4 + 2e^-$ [1]

(b) Which electrode is the cathode and which is the anode?

Pb (anode) [½] ; PbO_2 (cathode) [½]

(c) The actual voltage produced by each of the six cells is about 2.2 V which is different to the value predicted using the E° table. Why is this?

1.46 − (−0.36) = 1.82 V Predicted – assumes standard conditions – $[H^+]$ = 1 mol L^{-1} where as $[H_2SO_4]$ is given as 4 mol L^{-1} [1]

(d) Write an equation for the overall reaction which occurs when the battery is being recharged.

$2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2H_2SO_4$ [2]

(e) Sulfuric acid is more dense than water. Explain why measuring the density of the sulphuric acid in the battery can give an indication as to how 'charged' the battery is.

As the battery is discharged H_2SO_4 is consumed and so the density of the electrolyte decreases. The lower the density, the flatter the battery [2]

(2 + 1 + 1 + 2 + 2 marks)

192 176

6. A vitamin C enriched fruit-flavoured cordial, that can be diluted with water to make a drink, contains citric acid ($C_6H_8O_7$), vitamin C ($C_6H_8O_6$) , cane sugar, artificial blackberry flavouring and a preservative. The chemical name for vitamin C is ascorbic acid.

The cordial was analysed to determine the amount of citric acid and vitamin C present. Vitamin C can be determined, by oxidation, to dehydroascorbic acid, with a solution containing I_3^-, according to the equation:

$$I_3^-(aq) + C_6H_8O_6(aq) \longrightarrow 3I^-(aq) + 2H^+(aq) + C_6H_6O_6(aq)$$

(a) A 30.0 mL sample of the undiluted cordial was found to react completely with 19.87 mL of 0.0150 mol L^{-1} I_3^- solution. Calculate the concentration, in mgL^{-1}, of vitamin C in the undiluted cordial.

The total amount of acid (ascorbic and citric) can be measured by titration with a solution of sodium hydroxide. From this calculation and your answer to (a) above, the citric acid content can be determined.

(b) A second 30.0 mL sample of the undiluted cordial was titrated with 0.0922 molL^{-1} NaOH. A volume of 9.18 mL was required for complete neutralization. Assuming both citric acid and ascorbic acid are monoprotic acids (see note at end) and that they are the only acids present, calculate the concentration, in mg L^{-1}, of citric acid in the undiluted cordial.

(c)The cordial is intended to be diluted with water for drinking purposes by mixing one part cordial with four parts water. What volume of this final (diluted drink) should be consumed each day if the drinker is to obtain a daily dose of 250 mg of vitamin C.

AA = ascorbic acid
CA = citric acid

(a) $n(I_3^-) = \frac{19.87 \times 0.0150}{1000}$

$= 2.98 \times 10^{-4}$ mol [1]

$\therefore n(AA) = 2.98 \times 10^{-4}$ mol

$\therefore [AA] = \frac{n}{V} = \frac{2.98 \times 10^{-4}}{0.0300}$

$= 9.94 \times 10^{-3}$ mol L^{-1} [1]

$= 9.94 \times 10^{-3} \times 176$

$= 1.75$ gL^{-1}

$= 1.75 \times 10^{3}$ mgL^{-1} [1]

(b) $n(OH^-) = \frac{9.18 \times 0.0922}{1000}$

$= 8.46 \times 10^{-4}$ mol [1]

$\therefore n(\text{acids in total}) = 8.46 \times 10^{-4}$ [1]

$n(AA) = 2.98 \times 10^{-4}$ mol (from (a))

$\therefore n(CA) = 5.48 \times 10^{-4}$ mol [1]

$\therefore [CA] = \frac{n}{V} = \frac{5.48 \times 10^{-4}}{0.0300}$

$= 0.01827$ mol L^{-1}

$= 3.51$ g L^{-1}

$= 3.51 \times 10^3$ mg L^{-1} [1]

(c) dilution = 1/5 ⇒ $[AA]_{dilute} = 350$ mg L^{-1} [1]

$C\left(\frac{mg}{L}\right) \times V(L) = m(mg)$, with $C = 350$, $V = ?$, $m = 250$

$V_{(L)} = \frac{250}{350}$

$= 0.714$ L [1]

(3 + 4 + 2 marks)

Note: although ascorbic acid is diprotic is doesn't actually donate the second proton unless the conditions are very alkaline – this means for determining acidity in juices we can assume it behaves as a monoprotic acid