Electrochemistry - 2021

1. Nov/2020/Paper_41/No.3

(a) Identify the substances liberated at the anode and at the cathode during the electrolysis of aqueous sodium sulfate, $Na_2SO_4(aq)$.

anode .....

cathode .....

[1]

(b) When molten sodium chloride is electrolysed, chlorine is liberated at the anode and sodium is liberated at the cathode.

A sample of molten sodium chloride is electrolysed for 1.50 hours using a current of 4.50 A.

Calculate the volume of chlorine and the mass of sodium that are liberated under room conditions.

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volume of chlorine = ... dm^3

mass of sodium = ... g

[4]

(c) The equation representing the standard electrode potential, $E^{\ominus}$, for the reduction of $MnO_4^-(aq)$ to $Mn^{2+}(aq)$ in acid solution is given.

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightleftharpoons Mn^{2+}(aq) + 4H_2O(l) \qquad E^{\ominus} = +1.52\,V$$

(i) Draw a diagram of the apparatus that would be used to measure the $E^{\ominus}$ value of this half-cell. Your diagram should be fully labelled to identify all apparatus, substances and conditions.

[4]

(ii) Use the *Data Booklet* to identify a substance that could be used to oxidise Mn^{2+} ions to MnO_4^- ions under standard conditions.

Write an equation for the reaction.

.....

.....

..... [2]

[Total: 11]

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2. Nov/2020/Paper_42/No.4

(a) Identify the substances liberated at the anode and at the cathode during the electrolysis of saturated KC*l*(aq).

at the anode .....

at the cathode .....

[1]

(b) When dilute sulfuric acid is electrolysed, oxygen is liberated at the anode.

Dilute sulfuric acid is electrolysed for 15.0 minutes using a current of 0.750A.

Calculate the volume of oxygen that is liberated under room conditions.

volume of oxygen = ... cm^3 [3]

(c) The halogens chlorine, bromine and iodine differ in their strengths as oxidising agents. These strengths are indicated by the $E^{\ominus}$ values for these halogens.

(i) Give the $E^{\ominus}$ values for chlorine, bromine and iodine acting as oxidising agents.

..... [1]

(ii) Deduce which of chlorine, bromine and iodine will react with a solution of $Sn^{2+}(aq)$ under standard conditions.

Explain your answer. Include a relevant equation in your explanation.

.....

.....

..... [3]

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(iii) An excess of chlorine is added to a solution of acidified $Mn^{2+}(aq)$ under standard conditions.

Give the formula of the product of this reaction that contains manganese.

..... [1]

(d) An electrochemical cell can be made by connecting an Fe^{3+}/Fe^{2+} half-cell to an $S_2O_8^{2-}/SO_4^{2-}$ half-cell under standard conditions.

(i) Calculate the standard cell potential of this electrochemical cell.

$E^{\ominus}_{cell}$ = ... V [1]

(ii) State the material that should be used as the electrode in each half-cell.

in the Fe^{3+}/Fe^{2+} half-cell .....

in the $S_2O_8^{2-}/SO_4^{2-}$ half-cell .....
[1]

(iii) Describe **one** change to each half-cell that would **increase** the value of the cell potential. The temperature should remain at 298 K.

Fe^{3+}/Fe^{2+} half-cell .....

.....

$S_2O_8^{2-}/SO_4^{2-}$ half-cell .....

.....
[1]

[Total: 12]

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3. March/2020/Paper_42/No.3

Gold is an unreactive metal that can only be oxidised under specific conditions.

(a) The standard electrode potential, $E^{\ominus}$, of $Au^{3+}(aq)/Au(s)$ is +1.50 V.

(i) Define the term *standard electrode potential*.

.....

.....

..... [2]

(ii) Draw a fully labelled diagram of the apparatus that should be used to measure the standard cell potential, $E^{\ominus}_{cell}$, of $Au^{3+}(aq)/Au(s)$ and $HNO_3(aq)/NO(g)$.

Include all necessary chemicals.

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[4]

Some relevant half-equations and their standard electrode potentials are given.

	half-equation	$E^{\ominus}$/V
1	$Au^{3+}(aq) + 3e^- \rightleftharpoons Au(s)$	+1.50
2	$[AuCl_4]^-(aq) + 3e^- \rightleftharpoons Au(s) + 4Cl^-(aq)$	+1.00
3	$NO_3^-(aq) + 4H^+(aq) + 3e^- \rightleftharpoons NO(g) + 2H_2O(l)$	+0.96

(iii) Write an ionic equation to show the spontaneous reaction that occurs when an electric current is drawn from the cell in **(a)(ii)**.

..... [1]

(iv) Calculate the $E^{\ominus}_{cell}$ of the reaction in **(a)(iii)**.

$E^{\ominus}_{cell}$ = ... V [1]

(v) Gold can be oxidised by a mixture of concentrated hydrochloric acid and concentrated nitric acid, known as *aqua regia*. Concentrated hydrochloric acid is 12 mol dm^{-3}. Concentrated nitric acid is 16 mol dm^{-3}.

Explain why *aqua regia* is able to dissolve gold.

In your answer, state and explain what effect the use of concentrated hydrochloric acid and concentrated nitric acid have on the *E* values of half-equations 2 and 3.

.....

.....

.....

.....

.....

..... [3]

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(b) Aqueous gold(III) chloride, $AuCl_3$, reacts with aqueous hydrogen peroxide, H_2O_2, under certain conditions, forming Au, O_2 and HCl.

A student carries out separate experiments using different initial concentrations of $AuCl_3$ and H_2O_2. The initial rate of each reaction is measured.

The table shows the results that are obtained.

experiment	$[AuCl_3]$ / mol dm^{-3}	$[H_2O_2]$ / mol dm^{-3}	rate of production of $O_2(g)$ / dm^3 minute^{-1}
1	0.05	0.50	7.66×10^{-2}
2	0.10	0.50	1.53×10^{-1}
3	0.15	1.00	4.60×10^{-1}

(i) Write an equation for the reaction of $AuCl_3$ with H_2O_2.

..... [1]

(ii) Determine the rate equation of the reaction.

Show your reasoning, quoting data from the table.

.....

.....

.....

.....

..... [3]

(iii) Use the results of experiment 2 to calculate the value of the rate constant, *k*, for this reaction.

Include the units of *k*.

rate constant, *k* = ...

units = ...

[2]

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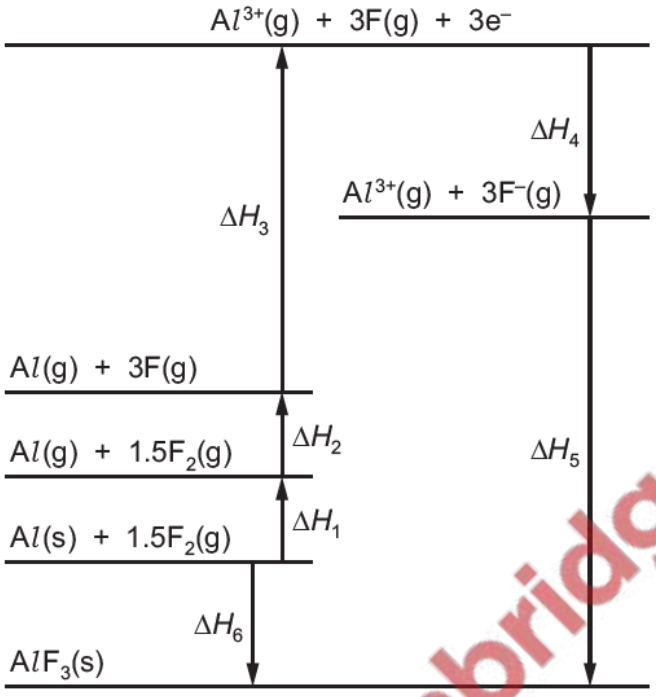
(c) $Al F_3$ is an ionic compound.

The Born–Haber cycle for the formation of $Al F_3$ is shown.



(i) Name the enthalpy changes labelled ΔH_4 and ΔH_6.

ΔH_4 = ...

ΔH_6 = ...

[2]

(ii) Use the data in the table and data from the *Data Booklet* to calculate the lattice energy of $Al F_3$.

process	enthalpy change / kJ mol^{-1}
$Al(s) \rightarrow Al(g)$	+326
$Al(g) \rightarrow Al^{3+}(g)$	+5137
$F(g) \rightarrow F^-(g)$	–328
$Al(s) + 1.5F_2(g) \rightarrow AlF_3(s)$	–1504

lattice energy of $Al F_3$ = ... kJ mol^{-1} [2]

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(iii) Scandium fluoride, ScF_3, is an ionic compound.

Use data from the *Data Booklet* to suggest how the lattice energy of AlF_3 compares with the lattice energy of ScF_3.

Explain your answer.

.....

.....

..... [2]

(d) AlF_3 is sparingly soluble in water. The concentration of its saturated solution at 298 K is 6.5×10^{-2} mol dm^{-3}.

(i) Write an expression for the solubility product, K_{sp}, of AlF_3.

K_{sp} = ... [1]

(ii) Calculate the numerical value of K_{sp} for AlF_3 at 298 K.

K_{sp} = ...
[1]

[Total: 25]

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4. June/2020/Paper_41/No.3

The overall reaction for photosynthesis is shown.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Water is oxidised in this process according to the following half-equation.

$$2H_2O \rightarrow O_2 + 4H^+ + 4e^- \qquad \text{half-equation 1}$$

(a) (i) Use these equations to deduce the half-equation for the reduction of carbon dioxide in this process.

[2]

(ii) Draw a fully labelled diagram of the apparatus that should be used to measure the standard electrode potential, $E^\ominus$, of $O_2(g)$ in half-equation 1 under standard conditions. Include all necessary chemicals.

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[4]

(iii) For the cell drawn in **(a)(ii)**, use the *Data Booklet* to calculate the $E^\ominus_{cell}$ and deduce which electrode is positive.

$E^\ominus_{cell}$ = ... V

identity of the positive electrode = ...

[1]

5. June/2020/Paper_41/No.7a

(a) Silver carbonate, Ag_2CO_3, is sparingly soluble in water. The numerical value of the solubility product, K_{sp}, for silver carbonate is 6.3×10^{-12} at 25 °C.

(i) Write an expression for the solubility product, K_{sp}, of Ag_2CO_3, and state its units.

K_{sp} =

units = ...
[2]

(ii) Calculate the equilibrium concentration of Ag^+ in a saturated solution of Ag_2CO_3 at 25 °C.

$[Ag^+]$ = ... $mol\,dm^{-3}$ [1]

(iii) Solid Ag_2CO_3 is stirred at 25 °C with 0.050 $mol\,dm^{-3}$ $AgNO_3$ until no more Ag_2CO_3 dissolves.

Calculate the concentration of carbonate ions, $[CO_3^{2-}]$, in this solution.

$[CO_3^{2-}]$ = ... $mol\,dm^{-3}$ [1]

(iv) An electrochemical cell is set up to measure the electrode potential, E, for the Ag^+/Ag half-cell using the saturated $Ag_2CO_3(aq)$ with a standard hydrogen electrode.

Use the *Data Booklet*, your answer to **(a)(ii)**, and the Nernst equation to calculate the electrode potential, E, for this Ag^+/Ag half-cell.

E for Ag^+/Ag half-cell = ... V [2]

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6. June/2020/Paper_41/No.9

(a) Manganese(IV) oxide, MnO_2, catalyses the decomposition of hydrogen peroxide, H_2O_2, as shown.

$$2H_2O_2(aq) \xrightarrow{MnO_2} 2H_2O(l) + O_2(g)$$

The mechanism involves the formation of the intermediate species, Mn^{2+}, in the first step which is subsequently used up in the second step.

State and use relevant electrode potentials, $E^{\ominus}$, to construct **two** equations to show how MnO_2 can catalyse this reaction.

.....

.....

.....

.....

.....

equation 1 .....

equation 2 .....

[3]

(b) The equation for the decomposition of hydrogen peroxide without a catalyst is shown.

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

Under certain conditions this reaction is found to be first order with respect to hydrogen peroxide, with a rate constant, k, of $2.0 \times 10^{-6}\,s^{-1}$ at 298 K.

Calculate the initial rate of decomposition of a $0.75\,mol\,dm^{-3}$ hydrogen peroxide solution at 298 K.

initial rate = ... $mol\,dm^{-3}\,s^{-1}$ [1]

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(c) A four-step mechanism is suggested for the reaction between hydrogen peroxide and iodide ions in an acidic solution.

step 1 $H_2O_2 + I^- \rightarrow IO^- + H_2O$

step 2 $H^+ + IO^- \rightarrow HIO$

step 3 $HIO + I^- \rightarrow I_2 + OH^-$

step 4 $OH^- + H^+ \rightarrow H_2O$

Step 1 is the rate-determining step.

(i) State what is meant by the term *rate-determining step*.

.....

..... [1]

(ii) Use this mechanism to construct a balanced equation for this reaction.

..... [1]

(iii) Deduce the order of reaction with respect to each of the following.

H_2O_2 = ... I^- = ... H^+ = ... [1]

[Total: 7]

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7. June/2020/Paper_42/No.7a

(a) (i) Define the term *electron affinity*.

.....

.....

..... [2]

(ii) Define the term *lattice energy*.

.....

.....

..... [2]

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