Chem Factsheet

September 2002 Number 41

Answering Questions on Electrochemical Cells

This Factsheet assumes you know and understand the basics of cells and standard electrode potentials (covered in Factsheet 37). It will concentrate on applying that knowledge to examination questions on cells.

There are three main types of question on electrochemical cells. Actual examination questions will usually contain more than one of these.

(1) Recall of basic facts

You can be asked to give the following:

(a) a drawing/description of the standard hydrogen electrode.

(b) the definition for a standard electrode potential.

(c) a drawing of the apparatus used to measure standard electrode potentials

(d) an explanation of why a **high resistance** voltmeter is used.

(e) an explanation of why potassium nitrate is used for the salt bridge.

(f) a description and explanation of the trend in oxidising and reducing powers related to the $E^\ominus$ table of values.

All of these are covered in Factsheet 37.

Exam Hint: - *Exam questions on this topic always include some element of recall. Good candidates should be able to recall the answers to all the above questions quickly and accurately.*

(2) Writing the overall cell reaction

This depends on identifying which is the cathode and anode from the $E^\ominus$ values of the two electrodes.

The electrode with the smallest (meaning most negative or least positive) $E^\ominus$ value is the cathode.

The values of electrode potentials are usually given in a table, with the most negative at the top and the most positive at the bottom, like this

$Mg^{2+} + 2e^- \rightleftharpoons Mg$	-2.37
$Al^{3+} + 3e^- \rightleftharpoons Al$	-1.66
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	-0.76
$2H^+ + 2e^- \rightleftharpoons H_2$	0.00
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0.34
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0.54

If the $E^\ominus$ values are given in this format, the higher of the two in the list is the cathode.

Exam Hint: - *Examiners willl **not** always give you the $E^\ominus$ in this order. Many otherwise good candidates lose out through assuming that "the one on top is the cathode" without checking the values are in the correct order first.*

Worked Example

What is the cell reaction when the following half cells are combined?

$V^{3+} + e^- \rightleftharpoons V^{2+}$ $E^\ominus = -0.26V$

$Ni^{2+} + 2e^- \rightleftharpoons Ni$ $E^\ominus = -0.25V$

Method	Answer
Identify the cathode	$V^{2+}\vert V^{3+}$ is the more negative electrode so it is the cathode
Reverse the equation for the cathode.	$V^{2+} \rightleftharpoons V^{3+} + e^-$
Write down the equation for the anode	$Ni^{2+} + 2e^- \rightleftharpoons Ni$
"Balance" the electrons in the two equations	There are two electrons in the nickel equation but only one in the vanadium equation. So double the vanadium equation: $2V^{2+} \rightleftharpoons 2V^{3+} + 2e^-$
Combine the equations. Replace $\rightleftharpoons$ by $\rightarrow$ Cancel the electrons	$Ni^{2+} + 2e^- + 2V^{2+} \rightleftharpoons Ni + 2V^{3+} + 2e^-$ $Ni^{2+} + 2V^{2+} \rightarrow Ni + 2V^{3+}$

Question 1 at the end of the Factsheet provides further practice on this type of question.

(3) Calculating $E^\ominus$ cell

$E^\ominus$ cell = $E^\ominus$ (anode) – $E^\ominus$ (cathode)

Clearly, this type of calculation depends on identifying the cathode and anode from the $E^\ominus$ values again.

Note that the reactant at the anode is being (electrons are added) and that at the cathode oxidised (electrons removed), so this is equivalent to an alternative form which is often seen:

$E^\ominus$ cell = $E^\ominus$ (reactant being reduced) – $E^\ominus$ (reactant being oxidised))

Worked Example

What is $E^\ominus$ cell for $V^{3+}|V^{2+}$ combined with $Ni^{2+}|Ni$?

Answer

First, identify the cathode: here Vanadium is the cathode, as its $E^\ominus$ value is more negative.

Then use the equation: $E^\ominus$ cell = $E^\ominus$ (anode) – $E^\ominus$ (cathode)

$E^\ominus$ cell = (-0.25) – (-0.26)

= +0.01V

Take care with minus signs. Make sure you write all of them in your working, and if you are unsure - use your calculator!

Exam Hint: - *The overall answer should be **positive** for a real cell.*

Question 2 provides further practice on this type of example.

Questions

You will need information on $E^{\ominus}$ values (given in Factsheet 37) to answer these questions.

1. What is the overall cell equation when the following half cells are combined?

(a) $Mg^{2+}|Mg$ with $Cl_2|2Cl^-$

(b) $Al^{3+}|Al$ with $Ag^+|Ag$

(c) $Cu^{2+}|Cu$ with $Fe^{3+}|Fe^{2+}$

(d) $I_2|2I^-$ with $Fe^{2+}|Fe$

(e) $2H^+|H_2$ with $V^{3+}|V^{2+}$

(f) $Mg^{2+}|Mg$ with $Zn^{2+}|Zn$

(g) $V^{3+}|V^{2+}$ with $Fe^{2+}|Fe$

(h) $Fe^{3+}|Fe^{2+}$ with $Ag^+|Ag$

(i) $Cl_2|2Cl^-$ with $I_2|2I^-$

(j) $Al^{3+}|Al$ with $Zn^{2+}|Zn$

2. Calculate $E^{\ominus}$ cell for each of the cells in question 1.

3. (a) Draw the apparatus used to measure the standard electrode potential for an $Al^{3+}|Al$ half cell.

(b) An $Al^{3+}|Al$ half cell and an $I_2|2I^-$ half cell are combined.
(i) State which reactant is oxidised in the resulting cell reaction

(ii) Calculate the $E^{\ominus}$ value for the resulting cell.

4. (a) What is meant by a standard electrode potential?

(b) Given the following standard electrode potentials:

$Cu^{2+} + e^- \rightleftharpoons Cu^+$ $E^{\ominus} = +0.15$ V
$Cu^+ + e^- \rightleftharpoons Cu$ $E^{\ominus} = +0.52$ V

(i) Give the resulting reaction from combining the two half cells $Cu^{2+}|Cu^+$ and $Cu^+|Cu$

(ii) Predict what would happen if copper (i) sulphate was added to water.

Acknowledgements:
This Factsheet was researched and written by Sam Goodman
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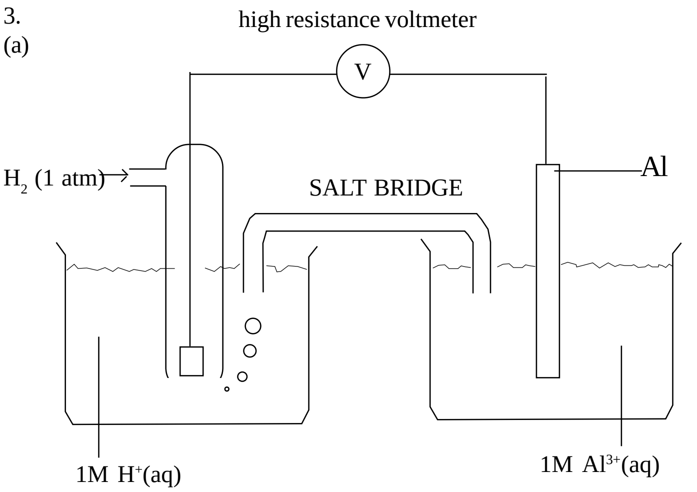
 ISSN 1351-5136

Answers

1.
(a) $Mg + Cl_2 \rightarrow Mg^{2+} + 2Cl^-$
(b) $Al + 3Ag^+ \rightarrow Al^{3+} + 3Ag$
(c) $Cu + 2Fe^{3+} \rightarrow Cu^{2+} + 2Fe^{2+}$
(d) $Fe + I_2 \rightarrow Fe^{2+} + 2I^-$
(e) $2V^{2+} + 2H^+ \rightarrow 2V^{3+} + H_2$
(f) $Mg^{2+} + Zn \rightarrow Mg + Zn^{2+}$
(g) $Fe + 2V^{3+} \rightarrow Fe^{2+} + 2V^{2+}$
(h) $Fe^{2+} + Ag^+ \rightarrow Fe^{3+} + Ag$
(i) $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$
(j) $3Zn^{2+} + 2Al \rightarrow 2Al^{3+} + 3Zn$

2.
(a) + 3.73V
(b) + 2.46V
(c) + 0.43V
(d) + 0.98V
(e) - 0.26V
(f) + 1.61V
(g) + 0.18V
(h) + 0.03V
(i) + 0.82V
(j) + 0.9V

3.
(a)



Temperature: 25° C

(b) (i) Reactant at cathode is oxidised: Al
(ii) $E^{\ominus}$ cell = +0.54 – (-1.66) = 2.20V

4.
(a) The SEP of a half cell is when a standard half cell (1 mol dm^{-3}, 25°C) is connected to a standard hydrogen electrode (1 mol dm^{-3} H^+ (aq), 1 atm, 25°C) using a high resistance voltmeter.

(b) (i) Cathode is $Cu^{2+} + e^- \rightleftharpoons Cu^+$
So equations are: $Cu^+ \rightleftharpoons Cu^{2+} + e^-$
$Cu^+ + e^- \rightleftharpoons Cu$
Combining: $2Cu^+ \rightarrow Cu + Cu^{2+}$

(ii) It would disproportionate to give copper metal and copper II sulphate