Electrochemistry Introduction

A Level

P P P

In electrochemistry, a potential difference between two half-cells is set up by having different redox couples and/or different concentrations of a given redox couple present.

Part A Introduction

The potential of the ______ side half-cell is measured relative to the ______ side one, so the cell potential is given by subtracting the reduction potential of the ______ side from the reduction potential of the ______ side. Standard reduction potentials can be tabulated, which correspond to values recorded under standard conditions against the standard ______ electrode. The conventional cell reaction consists of the right-hand side ______ and the left-hand side ______ (which can be thought of as subtracting the left-hand side ______), making sure that the number of electrons (n) transferred is the same for both sides.

Items:

right-hand | left-hand | platinum | silver | hydrogen | oxygen | oxidation | reduction

Part B Linking equations

Working out cell potentials can be useful in itself, but as a result of connections to other thermodynamic quantities, tabulated standard reduction potentials allow us to calculate, for example, equilibrium constants even of non-redox reactions or processes such as a salt dissolving.

Given that $\Delta_{\mathrm{r}}G^{\ominus} = -nFE^{\ominus} = -RT\ln K$, rearrange the equation for K (the equilibrium constant) as a function of n (the number of electrons transferred), F (the Faraday constant), $E^{\ominus}$ (the standard cell potential, for which you should use E^o in your expression), R (the universal gas constant) and T (the temperature).

The following symbols may be useful: `E^o, F, K, R, T, e, ln(), log(), n`

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Electrode Potential & Cell Potential 1

A Level
P P P

Essential Pre-Uni Chemistry L1.1

Name the element whose reduction is used as a standard by which all electrode potentials are measured.

- Hydrogen
- Iron
- Helium
- Lithium
- Platinum
- Oxygen
- Silver
- Fluorine

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Electrode Potential & Cell Potential 3

A Level

P P P

Essential Pre-Uni Chemistry L1.3

The standard electrode potential, $E^{\ominus}$, for the reduction, $\mathrm{Br_2\,(aq) + 2\,e^- \longrightarrow 2\,Br^-\,(aq)}$ is $1.09\,\mathrm{V}$. Give the $E^{\ominus}$ value for the reduction, $\frac{1}{2}\mathrm{Br_2\,(aq) + e^- \longrightarrow Br^-\,(aq)}$.

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Electrode Potential & Cell Potential 4

A Level

P P P

Essential Pre-Uni Chemistry L1.4

$E^{\ominus}$ for the reaction, $\mathrm{Ce^{4+}\,(aq) + e^- \longrightarrow Ce^{3+}\,(aq)}$ is $1.70\ \mathrm{V}$. Give the $E^{\ominus}$ value for the oxidation half-reaction, $\mathrm{Ce^{3+}\,(aq) \longrightarrow Ce^{4+}\,(aq) + e^-}$.

Gameboard:

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Electrode Potential & Cell Potential 5

A Level P P P

Essential Pre-Uni Chemistry L1.5

Reduction	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	-0.76
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	-0.44
$Cu^{2+}(aq) + e^- \longrightarrow Cu^{+}(aq)$	$+0.16$
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	$+0.34$
$Cu^{+}(aq) + e^- \longrightarrow Cu(s)$	$+0.52$
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	$+0.77$
$Ag^{+}(aq) + e^- \longrightarrow Ag(s)$	$+0.80$
$Cr_2O_7{}^{2-}(aq) + 6e^- + 14H^{+}(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	$+1.33$

Use the standard electrode potentials tabulated above to calculate the standard cell potentials due to the following reactions, giving your answers to 2 decimal places throughout:

Part A (a)

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

Part B (b)

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

Part C (c)

$$6\,Fe^{2+}\,(aq) + Cr_2O_7{}^{2-}\,(aq) + 14\,H^{+}\,(aq) \longrightarrow 6\,Fe^{3+}\,(aq) + 2\,Cr^{3+}\,(aq) + 7\,H_2O\,(l)$$

Part D (d)

$$Fe^{2+}\,(aq) + Zn\,(s) \longrightarrow Fe\,(s) + Zn^{2+}\,(aq)$$

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Free Energy Changes 9

A Level

P P P

Essential Pre-Uni Chemistry H2.9

The displacement of hydrogen from acid by iron,

$$2\,H^{+}\,(aq) + Fe\,(s) \rightleftharpoons Fe^{2+}\,(aq) + H_2\,(g)$$

has a standard cell potential of $0.44\ \mathrm{V}$. Find the associated standard Gibbs free energy change. (Faraday constant = $96\,485\ \mathrm{C\,mol^{-1}}$)

Gameboard:

STEM SMART Chemistry Week 37

Free Energy & Kc 1

A Level

P P P

Essential Pre-Uni Chemistry L2.1

Reduction	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	-0.76
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	-0.44
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	$+0.34$
$Cu^{+}(aq) + e^- \longrightarrow Cu(s)$	$+0.52$
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	$+0.77$
$Ag^{+}(aq) + e^- \longrightarrow Ag(s)$	$+0.80$
$Cr_2O_7{}^{2-}(aq) + 6e^- + 14H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	$+1.33$

Use the standard electrode potentials tabulated above to find $\Delta G^{\ominus}$ for the following reactions:

Part A **(a)**

$Ag^{+}(aq) + e^- \longrightarrow Ag(s)$

Part B **(b)**

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

Part C (c)

$$Fe^{3+}(aq) + 3\,e^{-} \longrightarrow Fe(s)$$

Gameboard:

STEM SMART Chemistry Week 37

Free Energy & Kc 2

Essential Pre-Uni Chemistry L2.2

A Level

Reduction	$E^{\ominus}$ / V
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	-0.76
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	-0.44
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	$+0.34$
$Cu^{+}(aq) + e^- \longrightarrow Cu(s)$	$+0.52$
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	$+0.77$
$Ag^{+}(aq) + e^- \longrightarrow Ag(s)$	$+0.80$
$Cr_2O_7{}^{2-}(aq) + 6e^- + 14H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	$+1.33$

Use the standard electrode potentials tabulated above to find $\Delta G^{\ominus}$ for the following reactions:

Part A (a)

$Ag^{+}(aq) + Fe^{2+}(aq) \longrightarrow Fe^{3+}(aq) + Ag(s)$. Give your answer to 1 significant figure.

Part B (b)

$3\,Zn\,(s) + Cr_2O_7{}^{2-}\,(aq) + 14\,H^+\,(aq) \longrightarrow 3\,Zn^{2+}\,(aq) + 2\,Cr^{3+}\,(aq) + 7\,H_2O\,(l)$. Give your answer to 3 significant figures.

Part C (c)

$2\,Cr\,(s) + 3\,Cu^{2+}\,(aq) \longrightarrow 2\,Cr^{3+}\,(aq) + 3\,Cu\,(s)$. Give your answer to 3 significant figures.

Gameboard:

STEM SMART Chemistry Week 37

Electrode Potential & Cell Potential 7

A Level

Essential Pre-Uni Chemistry L1.7

Reduction	E° / V
$Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$	-0.76
$Cr^{3+}(aq) + 3e^- \longrightarrow Cr(s)$	-0.74
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	-0.44
$Cu^{2+}(aq) + e^- \longrightarrow Cu^+(aq)$	$+0.16$
$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$	$+0.34$
$Cu^+(aq) + e^- \longrightarrow Cu(s)$	$+0.52$
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	$+0.77$
$Ag^+(aq) + e^- \longrightarrow Ag(s)$	$+0.80$
$Cr_2O_7{}^{2-}(aq) + 6e^- + 14H^+(aq) \longrightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	$+1.33$

Using the data tabulated above, calculate the standard cell potential for:

Part A (a)

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

Part B (b)

$$3\,Fe^{2+}\,(aq) \longrightarrow 2\,Fe^{3+}\,(aq) + Fe\,(s)$$

Part C (c)

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

Gameboard:

STEM SMART Chemistry Week 37

Combining Potentials

A Level
C C C

When half-cell potentials are combined to form a cell potential, the process is relatively straightforward: we balance the two half-equations to include the same number of electrons, and subtract the left-hand half-cell potential from the right-hand half-cell potential.

When two half-cell potentials need to be combined to instead form another half-cell potential, for a third half-reaction, the process is a little more complicated.

$\mathrm{A^{(n_1+n_2)+} + n_1e^- \longrightarrow A^{n_2+}}$ has a half-cell potential of x and $\mathrm{A^{n_2+} + n_2e^- \longrightarrow A}$ has a half-cell potential of y.

Derive an expression for the half-cell potential of the following reaction:

$$\mathrm{A^{(n_1+n_2)+} + (n_1 + n_2)e^- \longrightarrow A}$$

The following symbols may be useful: `n_1, n_2, x, y`

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