

## Electrochemistry Introduction

**Subject & topics:** Chemistry | Physical | Electrochemistry      **Stage & difficulty:** A Level P1

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

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

## Electrode Potential & Cell Potential 1

Essential Pre-Uni Chemistry L1.1

Subject & topics: Chemistry | Physical | Electrochemistry      Stage & difficulty: A Level P2

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

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

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## Electrode Potential & Cell Potential 3

Essential Pre-Uni Chemistry L1.3

Subject & topics: Chemistry | Physical | Electrochemistry      Stage & difficulty: A Level P2

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The standard electrode potential,  $E^\ominus$ , for the reduction,  $\text{Br}_2(\text{aq}) + 2\text{e}^- \rightarrow 2\text{Br}^-(\text{aq})$  is 1.09 V. Give the  $E^\ominus$  value for the reduction,  $\frac{1}{2}\text{Br}_2(\text{aq}) + \text{e}^- \rightarrow \text{Br}^-(\text{aq})$ .

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## Electrode Potential & Cell Potential 4

Essential Pre-Uni Chemistry L1.4

Subject & topics: Chemistry | Physical | Electrochemistry      Stage & difficulty: A Level P2

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

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## Electrode Potential & Cell Potential 5

Essential Pre-Uni Chemistry L1.5

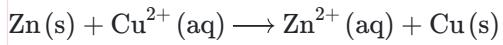
**Subject & topics:** Chemistry | Physical | Electrochemistry    **Stage & difficulty:** A Level P2

Reduction	$E^\circ / \text{V}$
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	−0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	−0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	−0.44
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightarrow \text{Cu}^+(\text{aq})$	+0.16
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.52
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{e}^- + 14\text{H}^+(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33

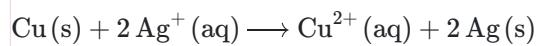
Use the standard electrode potentials tabulated above to calculate the standard cell potentials due to the following reactions, giving your answers to 2 decimal places throughout:

**Part A**

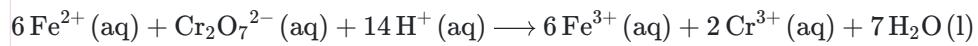
**(a)**



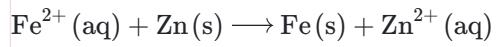
**Part B**  
**(b)**



**Part C**  
**(c)**



**Part D**  
**(d)**



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## Free Energy Changes 9

Essential Pre-Uni Chemistry H2.9

Subject & topics: Chemistry | Physical | Entropy    Stage & difficulty: A Level P2

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The displacement of hydrogen from acid by iron,



has a standard cell potential of 0.44 V. Find the associated standard Gibbs free energy change. (Faraday constant = 96 485 C mol<sup>-1</sup>)

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## Free Energy & Kc 1

Essential Pre-Uni Chemistry L2.1

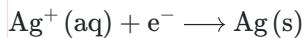
**Subject & topics:** Chemistry | Physical | Electrochemistry    **Stage & difficulty:** A Level P2

Reduction	$E^\ominus / \text{V}$
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Zn}(\text{s})$	−0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Cr}(\text{s})$	−0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe}(\text{s})$	−0.44
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cu}(\text{s})$	+0.34
$\text{Cu}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}(\text{s})$	+0.52
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$	+0.80
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{e}^- + 14\text{H}^+(\text{aq}) \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33

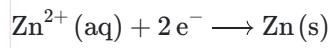
Use the standard electrode potentials tabulated above to find  $\Delta G^\ominus$  for the following reactions:

**Part A**

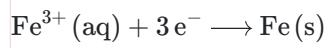
**(a)**



**Part B**  
**(b)**



**Part C**  
**(c)**



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## Free Energy & Kc 2

Essential Pre-Uni Chemistry L2.2

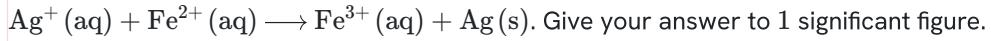
**Subject & topics:** Chemistry | Physical | Electrochemistry    **Stage & difficulty:** A Level P2

Reduction	$E^\ominus / \text{V}$
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Zn}(\text{s})$	−0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Cr}(\text{s})$	−0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe}(\text{s})$	−0.44
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cu}(\text{s})$	+0.34
$\text{Cu}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}(\text{s})$	+0.52
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \longrightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Ag}^+(\text{aq}) + \text{e}^- \longrightarrow \text{Ag}(\text{s})$	+0.80
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{e}^- + 14\text{H}^+(\text{aq}) \longrightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33

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

**Part A**

**(a)**



**Part B**  
**(b)**

$3 \text{Zn(s)} + \text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14 \text{H}^+(\text{aq}) \longrightarrow 3 \text{Zn}^{2+}(\text{aq}) + 2 \text{Cr}^{3+}(\text{aq}) + 7 \text{H}_2\text{O(l)}$ . Give your answer to 3 significant figures.

**Part C**  
**(c)**

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

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## Electrode Potential & Cell Potential 7

Essential Pre-Uni Chemistry L1.7

**Subject & topics:** Chemistry | Physical | Electrochemistry    **Stage & difficulty:** A Level P2

Reduction	$E^\circ / \text{V}$
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	−0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \rightarrow \text{Cr}(\text{s})$	−0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	−0.44
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightarrow \text{Cu}^+(\text{aq})$	+0.16
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.52
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightarrow \text{Ag}(\text{s})$	+0.80
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 6\text{e}^- + 14\text{H}^+(\text{aq}) \rightarrow 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33

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

**Part A**

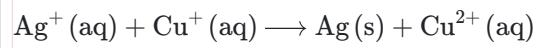
**(a)**



**Part B**  
**(b)**



**Part C**  
**(c)**



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## Combining Potentials

**Subject & topics:** Chemistry | Physical | Electrochemistry      **Stage & difficulty:** A Level C2

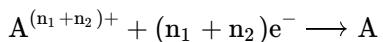
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When half-cell potentials are combined to form a cell potential, the process is relatively straightforward: we balance the two half-equations to include the same number of electrons, and subtract the left-hand half-cell potential from the right-hand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

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

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



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