



Physics. *You work it out.*

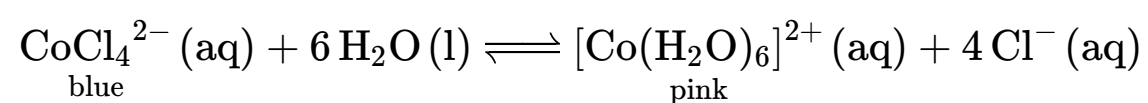
[Home](#) [Gameboard](#) [Chemistry](#) [Inorganic](#) [Transition Metals](#) [Cobalt Complexes Equilibrium](#)

Cobalt Complexes Equilibrium

A Level



This question is about the following equilibrium:



Part A Temperature dependence

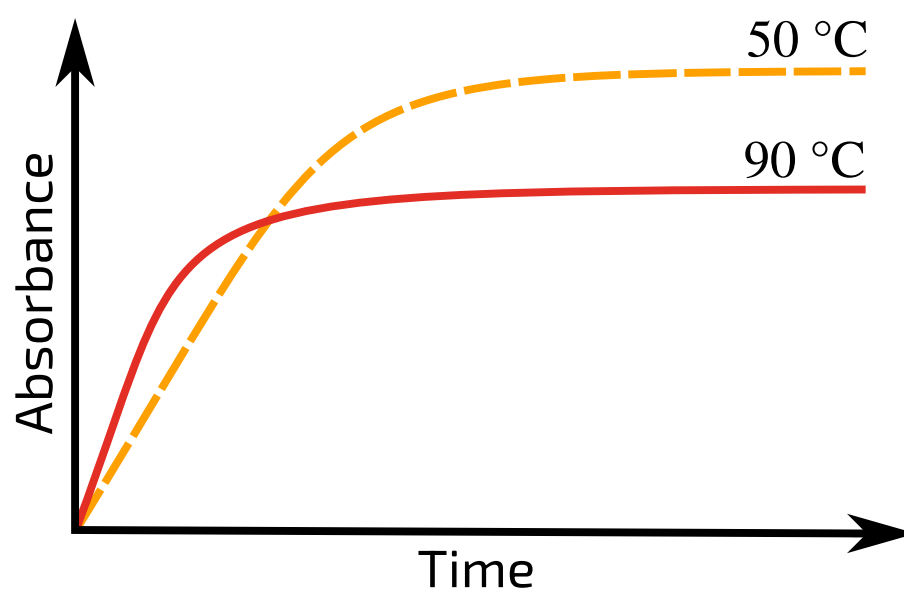
Two students decided to investigate this equilibrium. They are supplied with the equilibrium mixture at room temperature.

- One student heats 20 cm³ of the mixture to 50 °C.
- The other student heats 20 cm³ of the mixture to 90 °C.

The students use colorimetry to observe how the colour of the equilibrium mixture changes over time.

- The colorimeter is set up so that the greater the absorbance, the greater the concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$.
- The initial absorbance is set to zero.
- The absorbance is recorded every 30 seconds.

The students plot the graph below from the results of the experiment.



At the temperature, particles have more kinetic energy: they move faster and have collisions. Each collision is also likely to exceed the activation energy and therefore be successful, leading to a rate of reaction. This explains the steeper initial gradient.

However, at this temperature, the plateau occurs at a value of absorbance, indicating the equilibrium concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ is . This means the enthalpy of the products is than the enthalpy of the reactants.

Items:

more

less

higher

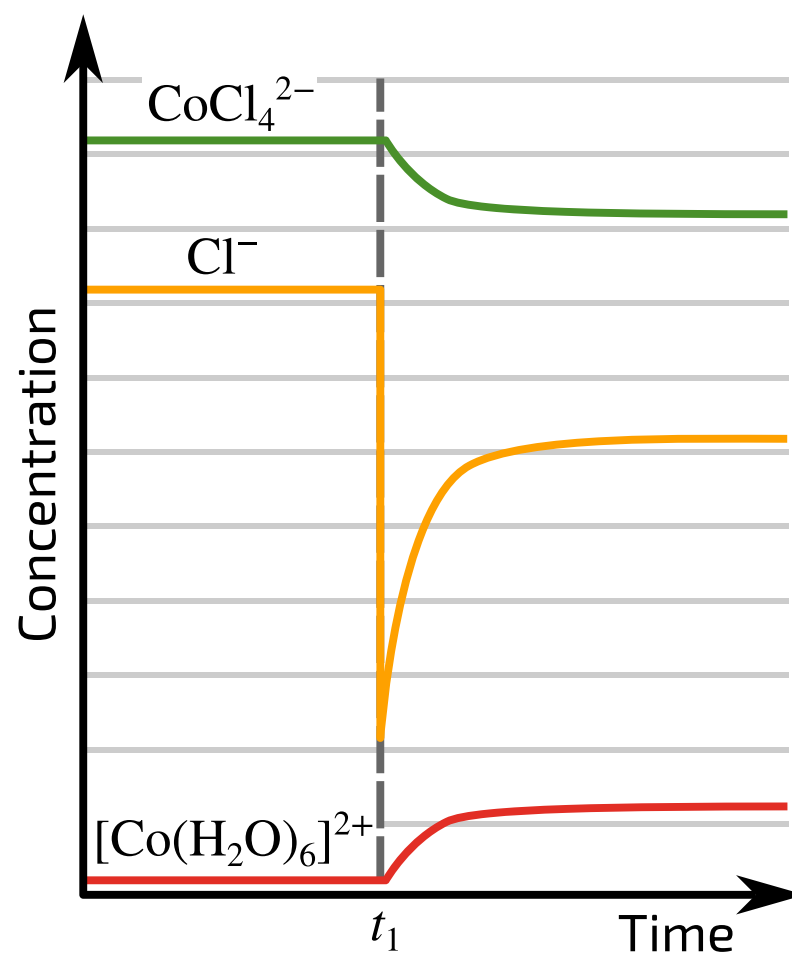
lower

fewer

Part B Silver nitrate

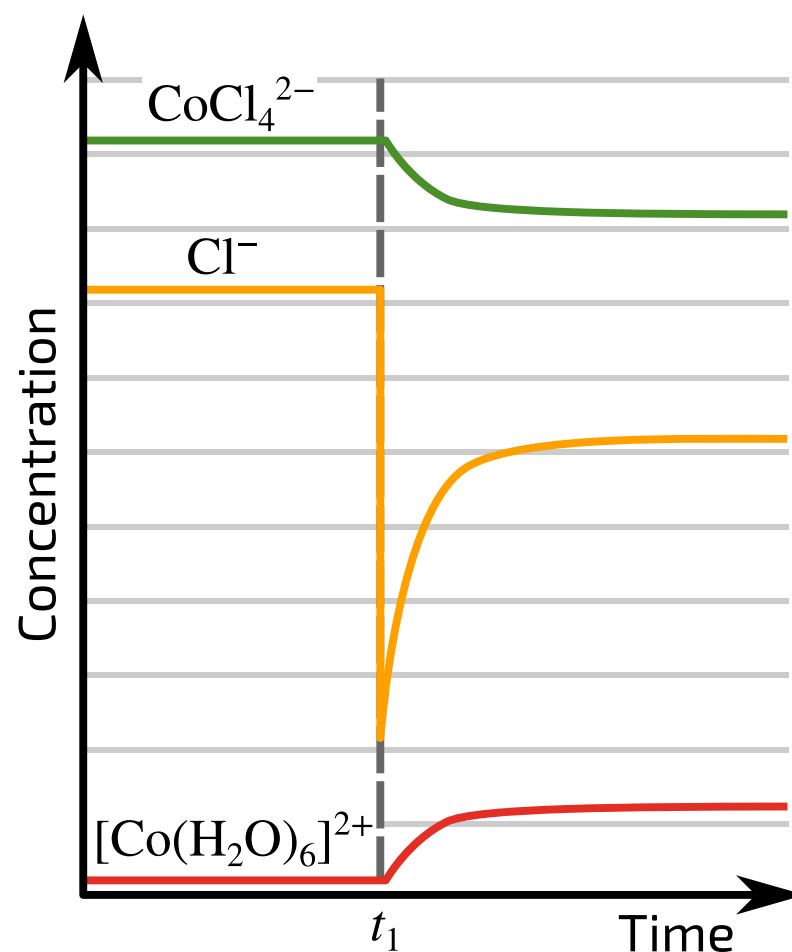
The students investigate how addition of aqueous silver nitrate, $\text{AgNO}_3(\text{aq})$, affects the equilibrium position. The graph below shows the changes in the equilibrium concentrations of CoCl_4^{2-} , Cl^- and $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$ after addition of the $\text{AgNO}_3(\text{aq})$.

The $\text{AgNO}_3(\text{aq})$ is added at time = t_1 .



Write an ionic equation, including state symbols, which explains the sharp drop in the Cl^- concentration at time = t_1 .

Part C Reequilibration



As a result of adding silver nitrate, the equilibrium shifts . The concentration of $[\text{Co}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ after time = t_1 , while the concentration of $[\text{CoCl}_4]^{2-}(\text{aq})$ by as much. The concentration of $\text{Cl}^-(\text{aq})$ by as much.

Items:

six times

equally

twice

increases

left

five times

four times

right

decreases

thrice

Part D Valence electrons

The colours of the two cobalt complexes are due to transitions of valence electrons between different energy levels.

How many valence electrons does a Co^{2+} ion have?

Part E Geometries

This ligand substitution reaction is accompanied by a change in geometry of the transition metal complex. Describe this change in the format "X to Y" (for example, "linear to trigonal planar").

Parts A-C adapted with permission from OCR, A Level Chemistry A, June 2022, H432/03, Question 4;
Parts D-E created for isaacphysics.org by Andrea Chlebikova

All materials on this site are licensed under the [Creative Commons license](https://creativecommons.org/licenses/by/4.0/), unless stated otherwise.

A Bidentate Ligand

A Level



A bidentate ligand has two lone pairs of electrons that it can donate to a transition metal ion, to form two coordinate bonds.

Part A Synthesis

A bidentate ligand can be produced by reacting 1,2-dichloroethane with two equivalents of ammonia.

Use the [structure editor](#) to draw the bidentate ligand that forms in this reaction.

Give your answer as a SMILES string.

In the editor, after drawing your structure, click on the round, yellow smiley face to generate a SMILES string. Copy the SMILES string and paste it in the answer box.

[Using the structure editor](#)

Part B Cobalt complex

The Co^{3+} ion can form a complex by associating with three molecules of this bidentate ligand per metal ion. How many different isomers of this complex exist?

Part C Complex cobalt complex

The Co^{3+} ion can also form a complex by associating with two chloride ions and two molecules of the bidentate ligand per metal ion. How many different isomers of this complex exist?

Part D EDTA

The bidentate ligand can be used to synthesise EDTA, by replacing each hydrogen bonded to a nitrogen with a side-chain featuring a carboxylate group. Each carboxylate group can donate a lone pair each. How would you describe this ligand, in reference to the number of dative bonds it forms?

Created for isaacphysics.org by Andrea Chlebikova

Gameboard:

STEM SMART Chemistry Week 50

All materials on this site are licensed under the [**Creative Commons license**](#), unless stated otherwise.

Palladium(II) salts

A Level

Palladium(II) salts can form square planar complexes. Successive addition of ammonia and hydrogen chloride to an aqueous palladium(II) salt produces, under different conditions, three compounds with empirical formula $\text{PdN}_2\text{H}_6\text{Cl}_2$. Two of these, **A** and **B**, are neutral complexes, with $M_r = 211$. **A** has a dipole moment whereas **B** has none. The third compound, **C**, is ionic with $M_r = 422$ and contains palladium in both its cation and anion.

Part A Compounds A and B

What is the formula of compounds **A** and **B**? Give your answer starting with the metal ion followed by any ligands.

Part B A and B isomerism

What kind of isomerism is present between compounds **A** and **B**?

Part C Compound C cation

Give the formula and charge of cation of compound **C** in the format $[\text{Pd}\cdots]^{n+}$.

Part D **Compound C anion**

Give the formula and charge of anion of compound **C** in the format $[\text{Pd}\dots]^n-$.

Adapted with permission from UCLES A-Level Chemistry June 1993, Paper 2, Question 1.

Gameboard:

STEM SMART Chemistry Week 50

All materials on this site are licensed under the **Creative Commons license**, unless stated otherwise.

Oxidation of Vanadium

A Level

A 0.0100 mol sample of an oxochloride of vanadium, VOCl_x , required 20.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ acidified potassium manganate(VII) for oxidation of the vanadium.

Part A Moles of electrons

How many moles of electrons were removed by the MnO_4^- ions?

Part B Change in oxidation state

By how much did the oxidation state of vanadium change? Enter, for example, -2 if it went down by two, +2 if it went up by two, 0 if it did not change.

Part C Value of x

What is the value of x in the formula VOCl_x ?

Adapted with permission from UCLES, A-Level Chemistry, June 1993, Paper 2, Question 2.

Gameboard:

STEM SMART Chemistry Week 50

Al and Fe

A Level



Aluminium, Al, and iron, Fe, are both metallic elements. However, their compounds show significant differences in their properties. For example, aluminium compounds are usually colourless and they contain the metal in only one oxidation state. In contrast, most iron compounds are coloured and the metal can be present in a variety of oxidation states.

Part A Al configuration

What is the ground-state electron configuration of Al?

Items:

[Ne]

[Ar]

[Kr]

[Xe]

3s

4s

3p

3d

4p

1

2

3

4

5

6

Part B Fe configuration

What is the ground-state electron configuration of Fe?

Items:

[Ne]

[Ar]

[Kr]

[Xe]

3s

4s

3p

3d

4p

1

2

3

4

5

6

Part C Al oxidation state

What is the only non-zero oxidation state observed for aluminium?

Part D Oxidation states of Fe

What are the two commonly found non-zero oxidation states for Fe?

☐ +1

☐ +2

☐ +3

☐ +4

☐ +6

☐ +7

☐ +8

Part E Maximum oxidation state of Fe

In theory, what is the highest oxidation state possible for Fe?

Part F Thiocyanate ion

A common test for the presence of Fe ions is the addition of thiocyanate ions, $(\text{SCN})^-$. The result is a blood-red colour, caused by the formation of the complex ion $[\text{Fe}(\text{SCN})]^{2+}$.

Using the [structure editor](#), draw a possible structure for the thiocyanate ion. Give your answer as a SMILES string copied from the editor (click the smiley face in the top left of the editor to generate this).

Adapted with permission from OCSEB, STEP Chemistry, June 1995, Question 6.

Gameboard:

STEM SMART Chemistry Week 50

All materials on this site are licensed under the [Creative Commons license](#), unless stated otherwise.

Essential Pre-Uni Chemistry L3.1



	Reduction	E^\ominus / V			Reduction	E^\ominus / V
1	$\text{As(V)} \longrightarrow \text{As(III)}$	+0.56		7	$\text{Cr(VI)} \longrightarrow \text{Cr(III)}$	+1.33
2	$\text{As(III)} \longrightarrow \text{As}$	+0.25		8	$\text{Cr(III)} \longrightarrow \text{Cr(II)}$	-0.41
3	$\text{As} \longrightarrow \text{As(-III)}$	-0.23		9	$\text{Cr(II)} \longrightarrow \text{Cr}$	-0.74
4	$\text{Mn(VII)} \longrightarrow \text{Mn(IV)}$	+1.70		10	$\text{I(VII)} \longrightarrow \text{I(V)}$	+1.60
5	$\text{Mn(IV)} \longrightarrow \text{Mn(II)}$	+1.23		11	$\text{I(V)} \longrightarrow \text{I}$	+1.19
6	$\text{Mn(II)} \longrightarrow \text{Mn}$	-1.19		12	$\text{I} \longrightarrow \text{I(-I)}$	+0.54

Part A Oxidising agent

Give the most powerful oxidising agent in the table (type it in without spaces, the same way it is listed in the table above).

Part B Reducing agent

Give the most powerful reducing agent in the table (type it in without spaces, the same way it is listed in the table above).

Essential Pre-Uni Chemistry L3.2

	Reduction	E^\ominus / V			Reduction	E^\ominus / V
1	$\text{As(V)} \longrightarrow \text{As(III)}$	+0.56		7	$\text{Cr(VI)} \longrightarrow \text{Cr(III)}$	+1.33
2	$\text{As(III)} \longrightarrow \text{As}$	+0.25		8	$\text{Cr(III)} \longrightarrow \text{Cr(II)}$	−0.41
3	$\text{As} \longrightarrow \text{As(−III)}$	−0.23		9	$\text{Cr(II)} \longrightarrow \text{Cr}$	−0.74
4	$\text{Mn(VII)} \longrightarrow \text{Mn(IV)}$	+1.70		10	$\text{I(VII)} \longrightarrow \text{I(V)}$	+1.60
5	$\text{Mn(IV)} \longrightarrow \text{Mn(II)}$	+1.23		11	$\text{I(V)} \longrightarrow \text{I}$	+1.19
6	$\text{Mn(II)} \longrightarrow \text{Mn}$	−1.19		12	$\text{I} \longrightarrow \text{I(−I)}$	+0.54

Select which of the states in the table could be oxidised spontaneously by elemental arsenic.

- ☐ As(V)
- ☐ As(III)
- ☐ As(−III)
- ☐ Mn(VII)
- ☐ Mn(IV)
- ☐ Mn(II)
- ☐ Mn
- ☐ Cr(VI)
- ☐ Cr(III)
- ☐ Cr(II)
- ☐ Cr
- ☐ I(VII)
- ☐ I(V)

- ☐ I
- ☐ $I(-I)$
- ☐ none of the above

Gameboard:

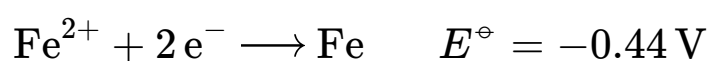
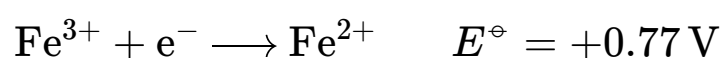
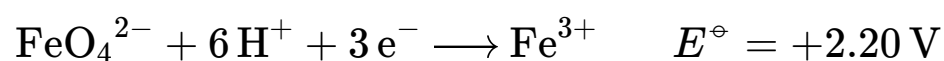
STEM SMART Chemistry Week 50

All materials on this site are licensed under the **Creative Commons license**, unless stated otherwise.

Essential Pre-Uni Chemistry L3.3

	Reduction	E^\ominus / V			Reduction	E^\ominus / V
1	$\text{As(V)} \longrightarrow \text{As(III)}$	+0.56		7	$\text{Cr(VI)} \longrightarrow \text{Cr(III)}$	+1.33
2	$\text{As(III)} \longrightarrow \text{As}$	+0.25		8	$\text{Cr(III)} \longrightarrow \text{Cr(II)}$	−0.41
3	$\text{As} \longrightarrow \text{As(−III)}$	−0.23		9	$\text{Cr(II)} \longrightarrow \text{Cr}$	−0.74
4	$\text{Mn(VII)} \longrightarrow \text{Mn(IV)}$	+1.70		10	$\text{I(VII)} \longrightarrow \text{I(V)}$	+1.60
5	$\text{Mn(IV)} \longrightarrow \text{Mn(II)}$	+1.23		11	$\text{I(V)} \longrightarrow \text{I}$	+1.19
6	$\text{Mn(II)} \longrightarrow \text{Mn}$	−1.19		12	$\text{I} \longrightarrow \text{I(−I)}$	+0.54

Some reduction half-equations involving iron are shown below:



Part A Oxidising Mn(IV)

Give the oxidation state of iron capable of oxidising Mn(IV).

Part B Highest oxidation states

For each of the four elements listed, select the highest oxidation state that could be attained using Fe^{3+} as the oxidising agent in aqueous acid: As, Cr, Mn, I

As

Cr

Mn

I

Part C Lowest oxidation states

For each of the three elements listed, select the lowest oxidation state capable of oxidising Fe^{2+} in aqueous acid: Cr, Mn, I

Cr

Mn

I

Part D Final oxidation states

For each of the four elements listed, select the final oxidation state spontaneously reached via reduction of a higher state on exposure to metallic iron: As, Cr, Mn, I

As

Cr

Mn

I

Gameboard:

STEM SMART Chemistry Week 50

All materials on this site are licensed under the [**Creative Commons license**](#), unless stated otherwise.



Physics. *You work it out.*

[Home](#) [Gameboard](#) [Chemistry](#) [Physical](#) [Electrochemistry](#) [Essential Pre-Uni Chemistry L2.3](#)

Essential Pre-Uni Chemistry L2.3

A Level



Calculate E^\ominus for reactions with:

Part A (a)

$$\Delta G^\ominus = -80 \text{ kJ mol}^{-1}; 1 \text{ e}^- \text{ transferred}$$

Part B (b)

$$\Delta G^\ominus = 16 \text{ kJ mol}^{-1}; 2 \text{ e}^- \text{ transferred}$$

Part C (c)

$$\Delta G^\ominus = -320 \text{ J mol}^{-1}; 2 \text{ e}^- \text{ transferred. Give your answer in mV to 2 significant figures.}$$

Part D (d)

$$K_c = 1.3 \times 10^6 \text{ @ } 298 \text{ K}; 1 \text{ e}^- \text{ transferred}$$

Part E (e)

$$K_c = 2.6 \times 10^{-6} \text{ @ } 298 \text{ K; } 3 \text{ e}^- \text{ transferred}$$

Part F (f)

$$K_c = 120 \text{ @ } 400 \text{ K; } 2 \text{ e}^- \text{ transferred}$$

Gameboard:

STEM SMART Chemistry Week 50

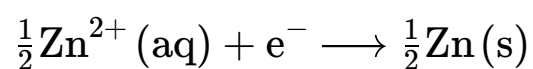
All materials on this site are licensed under the **Creative Commons license**, unless stated otherwise.

Essential Pre-Uni Chemistry L1.6

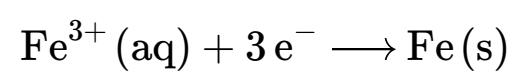
Reduction	E^\ominus / V
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Zn}(\text{s})$	-0.76
$\text{Cr}^{3+}(\text{aq}) + 3\text{e}^- \longrightarrow \text{Cr}(\text{s})$	-0.74
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe}(\text{s})$	-0.44
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \longrightarrow \text{Cu}^+(\text{aq})$	+0.16
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cu}(\text{s})$	+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

Using the data tabulated above, calculate the standard electrode potentials for the following reductions:

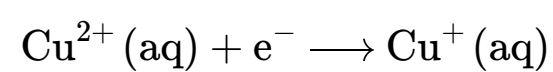
Part A (a)



Part B (b)



Part C (c)



Part D (d)

