

## Map of the unit: The Steel Story

This shows the relationship between the Storyline, the Activities and the Chemical Ideas. To aid planning, laboratory-based practical work is indicated by (P), activities involving IT skills are indicated by (IT) and those developing study skills by (S).

ACTIVITIES	CHEMICAL STORYLINE	CHEMICAL IDEAS
<b>SS1.1</b> How much manganese is there in a paper clip? (P) <b>SS1.2</b> A redox titration (P)	<b>SS1</b> WHAT IS STEEL?	<b>9.1</b> <i>Oxidation and reduction (revision)</i> <b>6.7</b> Where does colour come from?
<b>SS2.1</b> Why is blast furnace iron so impure? <b>SS2.2</b> What changes occur during steelmaking? (IT) <b>SS2.3</b> Getting the 'heat balance' right (optional extension) <b>SS2.4</b> How much aluminium do we need to add? (optional extension) <b>SS2.5</b> Which is the right steel for the job? (optional extension)	<b>SS2</b> HOW IS STEEL MADE?	<b>6.1</b> <i>Light and electrons (revision)</i>
<b>SS3.1</b> A simple redox reaction (P) <b>SS3.2</b> Simple electrochemical cells (P) <b>SS3.3</b> More electrochemical cells (P) <b>SS3.4</b> How does steel rust? (P) <b>SS3.5</b> Understanding redox reactions (S)	<b>SS3</b> RUSTING	<b>9.2</b> Redox reactions and electrode potentials <b>9.3</b> Predicting the direction of redox reactions
	<b>SS4</b> RECYCLING STEEL	
<b>SS5.1</b> Investigating the oxidation states of vanadium (P) <b>SS5.2</b> How do transition metal ions act as catalysts? (P) <b>SS5.3</b> Looking at some transition metal complexes (P)	<b>SS5</b> A CLOSER LOOK AT THE ELEMENTS IN STEEL	<b>11.5</b> The d block: characteristics of transition elements <b>2.4</b> <i>Electronic structure: sub-shells and orbitals (revision)</i> <b>10.5</b> <i>How do catalysts work? (revision)</i> <b>11.6</b> The d block: complex formation <b>9.4</b> The effect of complexing on redox reactions
<b>SS6</b> Check your notes on <b>The Steel Story</b> (S)	<b>SS6</b> SUMMARY	

**Note** Chemical Ideas shown in italics are revisited from earlier units.

# THE STEEL STORY

## Relation to other units

It is suggested that this teaching unit should be ninth in the course, although by this stage a certain amount of flexibility is possible.

**The Elements of Life** introduces atomic structure, energy levels in a hydrogen atom, atomic spectra and the arrangement of elements in the Periodic Table. Students learn to write electronic configurations in terms of s, p and d sub-shells in **From Minerals to Elements**, which also deals with the extraction of metals and introduces precipitation reactions, oxidation states and redox reactions. **From Minerals to Elements** also provides a brief introduction to transition metal chemistry and complex formation.

Isomerism was first met in **Developing Fuels**. Geometric isomerism was covered in **Polymer Revolution** and optical isomerism in **Engineering Proteins**. In this unit, students meet some inorganic examples.

Ideas about the role of catalysts were introduced in **Developing Fuels** and **The Atmosphere** and developed in **Engineering Proteins** with a study of enzyme-catalysed reactions. This unit discusses the action of transition metal ions both as homogeneous and heterogeneous catalysts.

The chemistry of coloured compounds is developed more fully in **Colour by Design**.

## Concept map

The concept map which follows shows how the major chemical ideas in this teaching unit develop throughout the course.

Concept	Introduced in unit	Developed in unit(s)	Assumed in unit(s)
Extraction of metals	M	SS	–
Atomic emission spectra	EL	–	SS, CD
Atomic orbitals and electron configuration	M	SS	CD
The Periodic Table	EL	M, SS, AA	all others
Redox	M	SS	AA
Standard electrode potentials and electrochemical cells	SS	–	–
Using electrode potentials to predict feasibility of reactions	SS	–	–
Transition metal chemistry	M	SS	–
Precipitation	M	SS, O	CD
Catalysis	DF	A, EP, SS, AA	several
Complexes	EL, M	SS	EP, CD
Shapes of molecules	EL	DF, PR, EP, MD	A, WM, DP, SS, AA, CD, O
Isomerism	DF	PR, EP	SS, AA, MD
Colour by absorption	SS	CD	–
Chemical equilibrium	A	EP, AA, O	SS
Metallic bonding	EL	SS	AA

## Advance warning

The following items needed for activities in this unit may not already be in your school, and might take a little time to obtain.

Activity	Item(s)	Essential/Optional	Typical quantity per experiment
SS1.1	Potassium iodate(VII) (periodate), $\text{KIO}_4$	Essential	0.5 g
	Colorimeter	Essential	
SS1.2	Spinach/spinach beet or rhubarb leaves	Essential	15 g spinach leaves or 5 g rhubarb leaves
SS2.2	The video 'The Steel Story' produced by Corus*	Optional	
SS5.1	Ammonium vanadate(V) (metavanadate), $\text{NH}_4\text{VO}_3$	Essential	0.25 g
SS5.2	Potassium sodium 2,3-dihydroxybutanedioate (potassium sodium tartrate or Rochelle salt)	Essential	2.5 g
	Cobalt(II) chloride, $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$	Essential	0.25 g
SS5.3	Nickel(II) chloride, $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$	Essential	1 g
	Ethylenediaminetetraacetic acid disodium salt ( $\text{Na}_2\text{H}_2\text{edta}$ )	Essential	0.5 g

\* Current suppliers are listed on the [Salters Advanced Chemistry Web Site](#).

## Storyline: answers to assignments

- For example, car bodies, steel girders for construction, cutlery, razor blades, boilers, mower blades, springs, paper clips, high-speed drill bits, fencing wire, door hinges, car tyre cords, drink cans, underwater gas pipes, etc.
- |                          |      |      |
|--------------------------|------|------|
|                          | Fe   | C    |
| Number of moles in 100 g | 1.68 | 0.37 |
| Mole %                   | 82.0 | 18.0 |

There are approximately 18 carbon atoms in every 100 atoms of product from a blast furnace.
- $\text{S} + 2\text{e}^- \rightarrow \text{S}^{2-}$   
This is a reduction because the sulphur atom gains two electrons.
  - $$\left[ \text{Mg} \right]^{2+} \quad \left[ \begin{array}{c} \cdot \times \\ \times \text{S} \times \\ \times \times \end{array} \right]^{2-}$$

(2.8)                  (2.8.8)
- It would be burnt as a fuel to keep down energy costs.
  - CO is poisonous. (It attaches itself to haemoglobin in the blood and prevents transport of oxygen around the body.)
  - |                      |                              |
|----------------------|------------------------------|
| Calcium silicate(IV) | $\text{CaSiO}_3$             |
| Calcium phosphate(V) | $\text{Ca}_3(\text{PO}_4)_2$ |
  - CaO reacts with acids to form salts. It reacts with water to produce an alkaline solution containing calcium hydroxide.  
$$\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2$$
  
P<sub>4</sub>O<sub>10</sub> reacts with bases to form salts. It reacts with water to produce an acidic solution containing phosphoric(V) acid.  
$$\text{P}_4\text{O}_{10} + 6\text{H}_2\text{O} \rightarrow 4\text{H}_3\text{PO}_4$$
- Silicon
  - Phosphorus
  - No. White phosphorus ignites spontaneously in air just above room temperature. Silicon is more stable in air and ignites at a much higher temperature.
  - Sulphur would be oxidised late on in the oxygen blow, after the removal of phosphorus. It is also difficult to remove completely. This is because it has an affinity for oxygen similar to iron at the high temperatures in the converter, but is present in much smaller amounts. So, at this late stage in the blow, large amounts of iron would be oxidised in preference to sulphur.
- If the blow were stopped at the appropriate carbon concentration, the concentration of phosphorus (and possibly manganese) would be too high. It would be difficult to stop the blow at a precise carbon concentration.
  - Individual batches of steel are produced to match precise customer specifications for the concentration of each element. Steel manufacture by a continuous process would be economical only if one type of steel were being produced. Otherwise, there would be a lot of wastage and accurate control of the composition would not be so easy.
- A cell is set up between the steel and the attached metal. Electrons flow to the half-cell at the more positive potential. The iron half-cell with  $E^\ominus = -0.44\text{V}$  is at a more positive potential than the magnesium and zinc half-cells, and so electrons will flow from Mg and Zn to Fe<sup>2+</sup>. Magnesium and zinc are oxidised in preference to iron.  
  
But the tin half-cell with  $E^\ominus = -0.14\text{V}$  is at a more positive potential than the iron half-cell. In this case, electrons will flow from the iron half-cell to the tin half-cell, so that iron is oxidised in preference to tin and rusting occurs more quickly.
- Bacteria which cause food spoilage are killed during heating. It is important to seal the hot food in an airtight container so that it is not recontaminated with bacteria from the air. It is also important that the can is full and as much air as possible is excluded, otherwise oxygen will react with some of the compounds in the food (eg fats will go rancid).
  - To protect the iron can from the food inside and the conditions outside, and so prevent rusting.
  - An electrochemical cell is set up between the tin and the iron in contact with moist air. The  $\text{Sn}^{2+}(\text{aq})/\text{Sn}(\text{s})$