Typical properties

4.1.3.2 · Atomic structure and the periodic table · revision notes

Three typical properties of the transition metals: many form ions with different charges, they form coloured compounds, and they and their compounds are useful as catalysts. You need examples using Cr, Mn, Fe, Co, Ni and Cu. This is in GCSE Chemistry only, not in Combined Science.

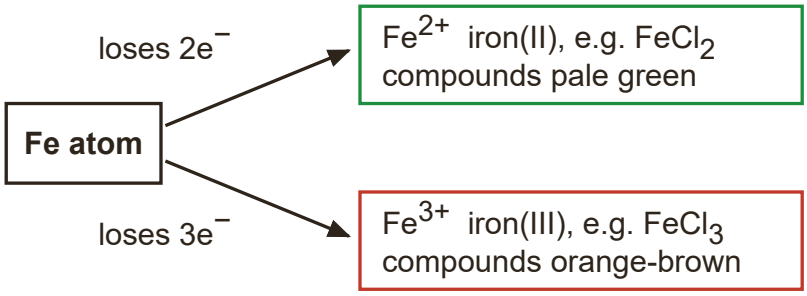
Key facts

- Typical properties: ions with different charges, coloured compounds, useful as catalysts
- Roman numeral = charge on the metal ion: iron(III) = Fe^{3+}
- Potassium manganate(VII): purple; potassium dichromate(VI): orange
- Group 1: only 1+ ions; white compounds (unless the other ion holds a transition metal)
- Iron: Fe^{2+} and Fe^{3+}; copper: Cu^{+} and Cu^{2+}
- Copper(II) sulfate solution: blue; iron(II): pale green; iron(III): orange-brown
- Catalysts: iron (Haber process); nickel (hydrogen + alkenes); manganese(IV) oxide (hydrogen peroxide)

Notes

Ions with different charges

- Many transition metals form ions with **different charges**: iron forms Fe^{2+} and Fe^{3+}; copper forms Cu^{+} and Cu^{2+}; chromium forms Cr^{2+} and Cr^{3+}; cobalt forms Co^{2+} and Co^{3+}.



One metal, two ions, two colours: typical of a transition metal.

- Group 1 metals only ever form 1+ ions.
- A Roman numeral in the name gives the charge on the metal ion: iron(II) chloride is $FeCl_2$; iron(III) chloride is $FeCl_3$; copper(II) oxide is CuO; copper(I) oxide is Cu_2O.

Coloured compounds

- Transition metal compounds are often **coloured**. Group 1 compounds are white and give colourless solutions, unless the other ion contains a transition metal (as in potassium manganate(VII)).
- Examples: copper(II) sulfate solution is blue; iron(II) compounds are pale green; iron(III) compounds are orange-brown; nickel(II) compounds are green; potassium manganate(VII) is purple; potassium dichromate(VI) is orange.
- Ions of the same metal with different charges can have different colours, e.g. iron(II) and iron(III).
- The colours are used to colour glass and pottery glazes, and to identify metal ions in tests.

Catalysts

- Transition metals and their compounds are useful as **catalysts**: they speed up reactions without being used up.
- Iron is the catalyst in the Haber process for making ammonia.
- Nickel is the catalyst for the reaction of hydrogen with alkenes.
- Manganese(IV) oxide catalyses the decomposition of hydrogen peroxide into water and oxygen.

How to answer each type of question

Compare transition metal compounds with Group 1 compounds 2 to 3 marks **Grade 4**

1. Use the three typical properties: different ion charges, coloured compounds, catalysts.
2. Write each point as a comparison with the Group 1 metal.

Example. Cobalt is a transition metal. Sodium is in Group 1.
Give **two** ways in which the compounds of cobalt are different from the compounds of sodium.

Model answer. Cobalt compounds are coloured, but sodium compounds are white (1). Cobalt forms ions with different charges (Co^{2+} and Co^{3+}), but sodium only forms Na^{+} ions (1).

Identify a transition metal from evidence 2 to 3 marks **Grade 5**

1. Look for coloured compounds, more than one ion charge, or use as a catalyst.
2. Match any named use (e.g. the Haber process) to the metal.
3. Give each piece of evidence as a separate point.

Example. Element **X** forms a pale green chloride, XCl_2, and an orange-brown chloride, XCl_3. **X** is the catalyst used to make ammonia.
(a) Suggest the identity of **X**.
(b) Give **two** pieces of evidence that **X** is a transition metal.

Model answer.

(a) iron (1)
(b) Any two: it forms coloured compounds (1); it forms ions with different charges, 2+ and 3+ (1); it is used as a catalyst (1).

Work out ion charges and names from formulae

1 mark each | Grade 6

1. Use the known charges of the non-metal ions (Cl^-, O^{2-}).
2. The metal's charge must balance them.
3. Write that charge as a Roman numeral in the name.

Example. Iron forms two chlorides, $FeCl_2$ and $FeCl_3$.
(a) Give the charge on the iron ion in $FeCl_3$.
(b) Name $FeCl_2$.

Model answer.

(a) 3+ (1), because three Cl^- ions balance it.
(b) iron(II) chloride (1)

Write the formula of a compound with a variable-charge ion

1 mark each | Grade 7

1. Read the charge from the Roman numeral.
2. Find the numbers of each ion that make the total charge zero.

Example. Give the formula of:
(a) copper(I) oxide
(b) chromium(III) oxide

Model answer.

(a) Cu_2O (1): two Cu^+ ions balance one O^{2-} ion.
(b) Cr_2O_3 (1): $2 \times (3+) = 6+$ balances $3 \times (2-) = 6-$.

Don’t lose marks

- Saying the metals themselves are coloured. It is their compounds that are typically coloured.
- Saying a catalyst is used up in the reaction. It is not used up.
- Reading the Roman numeral as the number of atoms: iron(III) oxide is Fe_2O_3, not FeO_3.
- Giving Group 1 behaviour, such as reacting vigorously with water, as a transition metal property.

More tips

Memory tricks

- Transition metals are 'three Cs': Coloured compounds, different Charges, Catalysts.
- Roman numeral = charge: (II) = 2+, (III) = 3+.
- Catalyst pairs: iron → Haber process; nickel → hydrogen + alkenes; manganese(IV) oxide → hydrogen peroxide.

Exam technique

- When asked for an example, name a compound or use involving Cr, Mn, Fe, Co, Ni or Cu.
- When comparing with Group 1, write a matched pair for each property.
- Use Roman numerals to work out formulae by balancing the charges.
- When asked which element, oxide or ion is most likely to be a catalyst or to form a coloured compound, use the periodic table and choose the transition metal (e.g. V, Cr, Co, Cu).

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4 — **State three typical transition metal properties**
Ions with different charges, coloured compounds, and use as catalysts.

Grade 5 — **Give examples of coloured compounds**
e.g. copper(II) sulfate solution is blue; iron(III) compounds are orange-brown.

Grade 5 — **Give examples of transition metal catalysts**
Iron in the Haber process; nickel for adding hydrogen to alkenes; manganese(IV) oxide for decomposing hydrogen peroxide.

Grade 5 — **Identify a transition metal from evidence**
Coloured compounds, more than one ion charge or use as a catalyst point to a transition metal.

Grade 6 — **Use Roman numerals for ion charges**
Iron(II) means Fe^{2+} and iron(III) means Fe^{3+}.

Grade 7 — **Write formulae with variable-charge ions**
Balance the charges, e.g. iron(III) oxide is Fe_2O_3 and copper(I) oxide is Cu_2O.

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