

2.3.4 Group reactions: formulae, solubility and thermal evidence

Name: _____ Class: _____ Date: _____

Total: 33 marks

KEY WORDS oxidation number

Objective

Use charge balance and particle models to predict unfamiliar Group-1/2 reactions. All questions and marking guidance are original.

1 Key knowledge and worked examples

An oxidation number is written as a signed number; a Roman numeral in a name gives the positive oxidation state. Iron(III) oxide is Fe_2O_3 : two Fe at +3 balance three O at -2 . This is different from counting atoms with a subscript.

■ Worked comparison

Calcium oxide is a basic oxide. With water, $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca}(\text{OH})_2$. With acid, $\text{CaO} + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{H}_2\text{O}$. Calcium hydroxide also neutralises acid: $\text{Ca}(\text{OH})_2 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + 2\text{H}_2\text{O}$. Check atoms and charge in each equation.

Down Group 2, hydroxide solubility increases but sulfate solubility decreases. Thermal stability of carbonates and nitrates increases: larger cations polarise their anions less strongly. Do not use the solubility trend to explain a decomposition temperature.

2 Practice

2.1 Write the names of FeCl_2 and FeCl_3 using Roman numerals. Write the formula of copper(II) nitrate and use charge balance to justify it. [4]

2.2 Write balanced equations for lithium burning to its oxide, sodium forming its peroxide, and potassium forming its superoxide in excess oxygen. Give the oxidation number of oxygen in each product. [6]

2.3 Write balanced equations for magnesium with steam and for barium with cold water. Compare the observed cold-water reactivity of Mg, Ca and Ba and explain the trend. [5]

3 Exam-style questions

3.1 For K_2O , write balanced equations with water and with dilute HCl. For $Ba(OH)_2$, write the full equation with HCl and the net ionic equation. State which changes are neutralisation rather than redox. [6]

3.2 Equal volumes of saturated $\text{Mg}(\text{OH})_2$ and $\text{Ba}(\text{OH})_2$ solutions at the same temperature are separately titrated with the same acid. Predict which needs more acid. Separately, predict which gives more precipitate when equal volumes of equally concentrated Mg^{2+} and Ba^{2+} solutions receive excess sulfate. Explain both, and explain why solubility is different from alkali strength. [5]

3.3 Magnesium carbonate decomposes at a lower temperature than barium carbonate. Explain using cation size. Write balanced equations for magnesium carbonate and magnesium nitrate on heating. Give tests/observations distinguishing the released gases. Explain why timing bubbles alone does not establish a decomposition temperature. [7]

Solutions

Original marking guidance: M1 method, A1 accuracy, B1 explanation.

2.1 Iron(II) chloride and iron(III) chloride. $\text{Cu}(\text{NO}_3)_2$; one Cu^{2+} needs two NO_3^- , total charge zero.

2.2 $4\text{Li} + \text{O}_2 \rightarrow 2\text{Li}_2\text{O}$, $\text{O} = -2$. $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}_2$, $\text{O} = -1$. $\text{K} + \text{O}_2 \rightarrow \text{KO}_2$, average $\text{O} = -\frac{1}{2}$. The products and conditions are specified; do not replace every oxygen product with a simple oxide.

2.3 $\text{Mg} + \text{H}_2\text{O}(\text{g}) \rightarrow \text{MgO} + \text{H}_2$; $\text{Ba} + 2\text{H}_2\text{O} \rightarrow \text{Ba}(\text{OH})_2 + \text{H}_2$. Cold-water reactivity increases $\text{Mg} < \text{Ca} < \text{Ba}$. Radius/shielding increase, weakening attraction to outer electrons so electron loss is easier.

3.1 $\text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{KOH}$; $\text{K}_2\text{O} + 2\text{HCl} \rightarrow 2\text{KCl} + \text{H}_2\text{O}$. $\text{Ba}(\text{OH})_2 + 2\text{HCl} \rightarrow \text{BaCl}_2 + 2\text{H}_2\text{O}$; $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$. The oxide–acid and hydroxide–acid changes are neutralisation; oxidation numbers do not change, so none of the stated changes is redox.

3.2 The saturated $\text{Ba}(\text{OH})_2$ solution needs more acid because hydroxide solubility increases down Group 2 and it contains more dissolved OH^- per equal volume. The Ba^{2+} solution gives more precipitate because sulfate solubility decreases down the group. Solubility controls how much dissolves; alkali strength concerns dissociation of the dissolved substance, so low solubility does not by itself mean weak alkali.

3.3 Mg^{2+} is smaller and has greater charge density, polarising the anion more strongly and lowering stability. $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$; $2\text{Mg}(\text{NO}_3)_2 \rightarrow 2\text{MgO} + 4\text{NO}_2 + \text{O}_2$. CO_2 turns limewater milky. O_2 relights a glowing splint; NO_2 is brown and acidic. Bubble timing also depends on heating rate/amount/apparatus, so temperature under controlled conditions must be measured. These are supervised methods; NO_2 requires approved ventilation.