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, $CaO + H_2O \rightarrow Ca(OH)_2$. With acid, $CaO + 2H^+ \rightarrow Ca^{2+} + H_2O$. Calcium hydroxide also neutralises acid: $Ca(OH)_2 + 2H^+ \rightarrow Ca^{2+} + 2H_2O$. 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 $Mg(OH)_2$ and $Ba(OH)_2$ 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. $Cu(NO_3)_2$; one Cu^{2+} needs two NO_3^-, total charge zero.

2.2 $4Li + O_2 \rightarrow 2Li_2O$, O = −2. $2Na + O_2 \rightarrow Na_2O_2$, O = −1. $K + O_2 \rightarrow KO_2$, average O = −½. The products and conditions are specified; do not replace every oxygen product with a simple oxide.

2.3 $Mg + H_2O(g) \rightarrow MgO + H_2$; $Ba + 2H_2O \rightarrow Ba(OH)_2 + H_2$. Cold-water reactivity increases Mg < Ca < Ba. Radius/shielding increase, weakening attraction to outer electrons so electron loss is easier.

3.1 $K_2O + H_2O \rightarrow 2KOH$; $K_2O + 2HCl \rightarrow 2KCl + H_2O$. $Ba(OH)_2 + 2HCl \rightarrow BaCl_2 + 2H_2O$; $H^+ + OH^- \rightarrow H_2O$. 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 $Ba(OH)_2$ 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. $MgCO_3 \rightarrow MgO + CO_2$; $2Mg(NO_3)_2 \rightarrow 2MgO + 4NO_2 + O_2$. 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.