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Topic 4.7: Types of Chemical Reactions

Worksheet · AP Chemistry

UNIT 4 · CHEMICAL REACTIONS

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How to Use This Worksheet

Work in order. Section A checks the five patterns, the three reaction families, and the activity series. Section B practises predicting products: replacements that do or do not run, cation swaps, a carbonate fizzing, and two reactions carried through with numbers. Section C combines classification, prediction and electron transfer in exam style.

Two reference sets are used throughout. The activity series, most reactive first, runs: potassium, sodium, calcium, magnesium, aluminium, zinc, iron, lead, hydrogen, copper, silver, gold. A free element displaces only elements below it. The solubility anchors are: $BaSO_4$, $CaCO_3$, AgCl and PbI_2 are insoluble; all nitrates, and all sodium and potassium salts, are soluble.

Molar masses you need: Mg 24.31 g/mol, H_2 2.02 g/mol, C_3H_8 44.10 g/mol, CO_2 44.01 g/mol, H_2O 18.02 g/mol, O_2 32.00 g/mol, $BaSO_4$ 233.39 g/mol. The molar volume of a gas at STP is 22.4 L/mol. Carry unrounded values through each calculation and round only the final answer, to three significant figures.

Classify with both systems every time: first the pattern (synthesis, decomposition, single replacement, double replacement, combustion), then the family (acid-base, precipitation, redox). Many reactions take one label from each.

Do not look at the answer key until you have attempted every question.

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Section A: Recall and Concepts

A1. For each pattern, state the general form and give one example equation. (a) Synthesis. (b) Decomposition. (c) Single replacement. (d) Double replacement. (e) Combustion of a hydrocarbon in excess oxygen.

A2. Define each term in one sentence. (a) Activity series. (b) Redox reaction. (c) Precipitation reaction. (d) Neutralisation. (e) Complete combustion.

A3. For each reaction, state which substance is oxidised and which is reduced, or state that the reaction is not redox. (a) $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$ (b) $Cl_2 + 2NaBr \rightarrow 2NaCl + Br_2$ (c) $HCl + NaOH \rightarrow NaCl + H_2O$ (d) $2Mg + O_2 \rightarrow 2MgO$

A4. Using the activity series in the introduction, state whether each single replacement reaction occurs. Where it does, write the balanced equation. (a) Copper metal is placed in zinc sulfate solution. (b) Zinc metal is placed in copper(II) sulfate solution. (c) Iron metal is placed in dilute hydrochloric acid. (d) Copper metal is placed in dilute hydrochloric acid. (e) Silver metal is placed in copper(II) nitrate solution.

A5. Complete and balance each equation. (a) $__ Na + __ Cl_2 \rightarrow __ NaCl$ (b) $__ H_2O_2 \rightarrow __ H_2O + __ O_2$ (c) $__ C_2H_6 + __ O_2 \rightarrow __ CO_2 + __ H_2O$ (d) $__ KClO_3 \rightarrow __ KCl + __ O_2$

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Section B: Core Practice

B1. Classify each reaction, giving every label that applies: the pattern, and the family where one applies. (a) $CaCO_3 \rightarrow CaO + CO_2$ (b) $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$ (c) $HCl + NaOH \rightarrow NaCl + H_2O$ (d) $Zn + 2HCl \rightarrow ZnCl_2 + H_2$ (e) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$ (f) $CaO + H_2O \rightarrow Ca(OH)_2$

B2. Magnesium ribbon is dropped into dilute hydrochloric acid and fizzes vigorously. (a) State the pattern of this reaction and write the balanced equation. (b) Calculate the moles of magnesium in 2.43 g of the metal. (c) Calculate the volume of hydrogen gas, measured at STP, that this mass of magnesium produces. (d) State which species is oxidised and which is reduced. (e) The flask stands on a balance throughout. Predict how the total mass of the flask and its contents changes as the magnesium reacts, and calculate that change.

B3. Predict the products of each double replacement. Write the balanced equation where a reaction occurs, and explain your decision each time. (a) Lead(II) nitrate solution is mixed with potassium iodide solution. (b) Calcium chloride solution is mixed with sodium carbonate solution. (c) Sodium chloride solution is mixed with potassium nitrate solution.

B4. A student adds dilute hydrochloric acid to solid calcium carbonate and sees fizzing. (a) Write the balanced equation for the reaction. (b) Name all three products. (c) Classify the reaction, giving a pattern label and a family label. (d) Explain what the fizzing is, and why it shows a chemical change rather than a physical one. (e) The student repeats the experiment with the flask sealed and standing on a balance. State what happens to the balance reading this time, and explain the difference from the open flask in terms of where the atoms go.

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B5. A camping stove burns propane, C_3H_8, in excess oxygen. (a) Calculate the moles of propane in 4.41 g. (b) Write the balanced equation for the complete combustion, and calculate the moles and the mass of oxygen used. (c) Calculate the masses of carbon dioxide and water formed. (d) Use your answers to show that mass is conserved in this reaction. (e) The stove is then run with its air inlet partly closed, so oxygen is in limited supply. State how the products change, and whether the mass of carbon dioxide formed from 4.41 g of propane rises, falls, or stays the same.

B6. A solution containing 0.0100 mol of $BaCl_2$ is mixed with excess sodium sulfate solution. (a) Write the balanced equation for the reaction. (b) Classify the reaction, giving a pattern label and a family label. (c) Calculate the mass of $BaSO_4$ precipitated. (d) State which two ions remain dissolved and unchanged. (e) The precipitate is filtered off, washed and dried before weighing. Give two reasons why the mass collected is likely to be slightly less than the value you calculated in part (c).

Section C: Exam Style

C1. A student places a piece of zinc metal in copper(II) sulfate solution. The blue colour of the solution slowly fades, a brown solid forms on the zinc, and the temperature of the solution rises. (a) Write the balanced equation for the reaction. (b) Give two classifications for this reaction, justifying each in one sentence. (c) State the oxidation number change for zinc and for copper, and hence state which species is oxidised and which is reduced. (d) Explain, in terms of the particles present, why the blue colour fades. (e) The student then places a piece of copper metal in zinc sulfate solution. Predict what is observed and explain your prediction.

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C2. A student tries to write the reaction between aluminium and copper(II) sulfate and produces: $Al + CuSO_4 \rightarrow AlSO_4 + Cu$. (a) Explain, using ion charges, why the product formula $AlSO_4$ is impossible, and state the correct formula for aluminium sulfate. (b) Write the correctly balanced equation for the reaction. (c) State whether the reaction occurs, justifying your answer with the activity series, and give one observation that would be seen.

C3. For each mixture, state whether a reaction occurs. Where it does, write the balanced equation and give one classification label. Where it does not, explain why not. (a) An iron nail is left standing in copper(II) sulfate solution. (b) A copper strip is left standing in zinc sulfate solution. (c) Dilute hydrochloric acid is poured onto sodium carbonate solution. (d) Silver nitrate solution is mixed with potassium chloride solution. (e) Sodium chloride solution is mixed with potassium nitrate solution.

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Answer Key

A1. (a) A + B → AB: two or more reactants combine into one product, e.g. $2Mg + O_2 \rightarrow 2MgO$. (b) AB → A + B: one reactant splits into two or more products, e.g. $CaCO_3 \rightarrow CaO + CO_2$. (c) A + BC → AC + B: a free element displaces another element from its compound, e.g. $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$. (d) AB + CD → AD + CB: two compounds exchange ions, e.g. $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$. (e) Hydrocarbon + $O_2 \rightarrow CO_2 + H_2O$, e.g. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$.

A2. (a) The ranking of elements by reactivity: a free element displaces only elements ranked below it from their compounds. (b) A reaction in which electrons are transferred, so oxidation numbers change: one substance loses electrons and is oxidised, another gains them and is reduced. (c) A reaction in solution in which ions combine to form an insoluble solid that leaves the solution as a precipitate. (d) The reaction of an acid with a base to form a salt and water. (e) The burning of a fuel in excess oxygen, so that every carbon atom forms CO_2 and every hydrogen atom forms H_2O.

A3. (a) Zinc is oxidised (0 to +2, losing electrons); copper(II) ions are reduced (+2 to 0, gaining electrons). (b) Chlorine is reduced (0 to −1, gaining electrons); bromide ions are oxidised (−1 to 0, losing electrons). (c) Not redox: hydrogen stays at +1, oxygen at −2, sodium at +1 and chlorine at −1 throughout; it is an acid-base reaction. (d) Magnesium is oxidised (0 to +2); oxygen is reduced (0 to −2).

A4. (a) No reaction: copper is below zinc in the series, so it cannot displace zinc. (b) Reaction: $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$. Zinc is above copper. (c) Reaction: $Fe + 2HCl \rightarrow FeCl_2 + H_2$. Iron is above hydrogen, so it displaces hydrogen from the acid. (d) No reaction: copper is below hydrogen, so it cannot displace hydrogen from the acid. (e) No reaction: silver is below copper in the series.

A5. (a) $2Na + Cl_2 \rightarrow 2NaCl$. (b) $2H_2O_2 \rightarrow 2H_2O + O_2$. (c) $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$. (d) $2KClO_3 \rightarrow 2KCl + 3O_2$.

B1. (a) Decomposition. Oxidation numbers do not change (Ca +2, C +4, O −2 throughout), so no family label applies. (b) Double replacement, and precipitation: the cations swap partners and $BaSO_4$ is insoluble. (c) Double replacement, and acid-base (neutralisation): a salt and water form, with no oxidation number changes. (d) Single replacement, and redox: zinc (0 to +2) displaces hydrogen (+1 to 0). (e) Combustion, and redox: carbon and hydrogen are oxidised and oxygen is reduced. (f) Synthesis: two compounds join into one product, with no oxidation number changes.

B2. (a) Single replacement: magnesium sits above hydrogen in the activity series and displaces it. $Mg + 2HCl \rightarrow MgCl_2 + H_2$. (b) Moles of Mg = 2.43 ÷ 24.31 = 0.100 mol. (c) The equation ratio is 1 : 1, so moles of H_2 = 0.100 mol. Volume at STP = 0.100 × 22.4 = 2.24 L. (d) Magnesium is oxidised (0 to +2 in Mg^{2+}); hydrogen ions are reduced (+1 to 0 in H_2). (e) The total mass falls, by the mass of the hydrogen that escapes as a gas: 0.100 × 2.02 = 0.202 g. Equivalently, the solution itself gains 2.43 − 0.202 = 2.23 g, because the magnesium's mass joins it as Mg^{2+} while the hydrogen bubbles away.

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B3. (a) Swap the cations: Pb^{2+} pairs with I^- and K^+ pairs with NO_3^-. PbI_2 is insoluble, so the reaction occurs: $Pb(NO_3)_2 + 2KI \rightarrow PbI_2 + 2KNO_3$, forming a yellow precipitate. (b) Swap the cations: Ca^{2+} pairs with CO_3^{2-} and Na^+ pairs with Cl^-. $CaCO_3$ is insoluble, so the reaction occurs: $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$, forming a white precipitate. (c) The swap would give $NaNO_3$ and KCl, but both are soluble; no precipitate, gas or water forms, so all four ions stay dissolved and no reaction occurs.

B4. (a) $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$. (b) Calcium chloride (the salt, dissolved in the water present), water, and carbon dioxide. (c) Pattern: double replacement, the calcium and hydrogen cations exchanging partners. Family: acid-base, an acid reacting with a carbonate base; it is also gas-forming. (d) The fizzing is carbon dioxide gas being produced and escaping. It shows a chemical change because a new substance, the gas, is being formed from the reactants; the bubbles are not the liquid boiling, because no heating is applied and the gas is a different substance from anything that was present before. (e) The reading stays constant. In the sealed flask the CO_2 cannot escape, so every atom that was present at the start is still inside at the end, only rearranged into new substances. In the open flask the reading falls because the CO_2 leaves, carrying its mass away with it.

B5. (a) Moles of C_3H_8 = 4.41 ÷ 44.10 = 0.100 mol. (b) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. Moles of O_2 = 5 × 0.100 = 0.500 mol; mass = 0.500 × 32.00 = 16.0 g. (c) Moles of CO_2 = 3 × 0.100 = 0.300 mol, mass = 0.300 × 44.01 = 13.2 g. Moles of H_2O = 4 × 0.100 = 0.400 mol, mass = 0.400 × 18.02 = 7.21 g. (d) Mass of reactants = 4.41 + 16.0 = 20.4 g. Mass of products = 13.2 + 7.21 = 20.4 g, to three significant figures. The totals agree, so mass is conserved, as it must be when every atom in the reactants appears in the products. (e) With oxygen limited, the combustion is incomplete: some carbon forms carbon monoxide or soot (carbon) instead of CO_2, so the mass of CO_2 from 4.41 g of propane falls. Less of the propane's carbon reaches CO_2, even though mass overall is still conserved.

B6. (a) $BaCl_2 + Na_2SO_4 \rightarrow BaSO_4 + 2NaCl$. (b) Pattern: double replacement. Family: precipitation, because $BaSO_4$ is insoluble and leaves the solution as a solid. (c) The equation ratio is 1 : 1, so moles of $BaSO_4$ = 0.0100 mol. Mass = 0.0100 × 233.39 = 2.33 g. (d) Na^+ and Cl^-: they appear unchanged on both sides of the equation and take no part in forming the solid. (e) Any two of: a little $BaSO_4$ remains stuck to the beaker, stirrer and filter paper during transfer; some very fine particles pass through the filter paper; a trace of $BaSO_4$ stays dissolved, because no solid is completely insoluble; some solid is lost when the filter paper is handled and dried.

C1. (a) $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$. (b) Single replacement, because the free element zinc takes the place of copper in its compound; and redox, because electrons are transferred, zinc atoms becoming Zn^{2+} ions while Cu^{2+} ions become copper atoms. (c) Zinc: 0 to +2, so zinc is oxidised. Copper: +2 to 0, so copper(II) ions are reduced. (d) The blue colour belongs to Cu^{2+} ions in solution. As the reaction proceeds those ions are converted into copper metal on the surface of the zinc, so their concentration falls and the colour fades; the Zn^{2+} ions replacing them are colourless. (e) Nothing is observed: the solution stays blue and the copper is unchanged. Copper is below zinc in the activity series, so it cannot displace zinc from its compound.

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C2. (a) Aluminium forms Al^{3+} ions and sulfate is SO_4^{2-}. In $AlSO_4$ the total charge would be +3 + (−2) = +1, not zero, and an ionic compound must be neutral overall. Two Al^{3+} ions (+6) balance three SO_4^{2-} ions (−6), so the correct formula is $Al_2(SO_4)_3$. (b) $2Al + 3CuSO_4 \rightarrow Al_2(SO_4)_3 + 3Cu$. (c) The reaction occurs: aluminium is above copper in the activity series, so it displaces copper from its salt. The blue colour of the solution fades as Cu^{2+} leaves it, and a brown coating of copper forms on the aluminium.

C3. (a) Reaction: $Fe + CuSO_4 \rightarrow FeSO_4 + Cu$. Single replacement (also redox): iron is above copper in the activity series. (b) No reaction: copper is below zinc, so it cannot displace zinc from zinc sulfate. (c) Reaction: $2HCl + Na_2CO_3 \rightarrow 2NaCl + H_2O + CO_2$. Acid-base: the acid reacts with the carbonate to give a salt, water and carbon dioxide, seen as effervescence. (d) Reaction: $AgNO_3 + KCl \rightarrow AgCl + KNO_3$. Double replacement (also precipitation): AgCl is insoluble and forms a white precipitate. (e) No reaction: swapping the cations would give $NaNO_3$ and KCl, both soluble, and no gas or water forms, so every ion remains dissolved.

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Topic 4.7 Quiz: Types of Chemical Reactions

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