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Topic 4.4: Physical and Chemical Changes

Worksheet · AP Chemistry

UNIT 4 · CHEMICAL REACTIONS

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How to Use This Worksheet

Work in order. Section A checks the ideas: the particle test that separates the two kinds of change, what breaks in each, dissolving, and the limits of evidence. Section B builds the skill: classifying real scenarios with particle-level justifications and working the energy numbers. Section C combines classification, conservation and claim-testing in exam style.

Every scenario in this worksheet is described completely in words. Where an equation or a value is needed, it is stated in the question, so each question can be answered from the text alone. In your answers, always justify a classification by saying what happens to the particles.

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

Section A: Recall and Concepts

A1. (a) State the single question that decides whether a change is physical or chemical. (b) In a physical change, the particles keep their identity. State three things about the particles that can still change. (c) In a chemical change, what happens to the bonds within the reactants, and what happens to the atoms? (d) State what is true of the elements present before and after a chemical change.

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A2. Classify each process as a physical or a chemical change, with one line of justification for each. (a) Water vapour depositing as ice crystals on a cold window. (b) Milk turning sour over several days. (c) A puddle of water drying up in sunlight. (d) A silver spoon tarnishing in air. (e) A sheet of paper being torn into strips.

A3. (a) When water boils, what is overcome: attractions between the molecules, or bonds within them? (b) What are the bubbles in boiling water made of? (c) A student claims boiling must be a chemical change because a gas is produced. Correct the claim using the particle picture. (d) State what would have to happen to the H_2O molecules themselves before the change could be called chemical.

A4. (a) Describe the particles present in solid sodium chloride, and the particles present after it dissolves in water. (b) Dissolving breaks the salt lattice apart. Explain why it is still classified as a physical change. (c) State a physical step that recovers the salt unchanged, and what its success shows. (d) Describe the particles when sugar dissolves in water, and state the difference from the salt case.

A5. (a) Name four observations that can act as evidence that a chemical change has occurred. (b) Give one physical change that produces bubbles, and explain why it is not a reaction. (c) Explain how a chemical change can take place with no visible sign at all. (d) Explain why "the change can be reversed" is a clue about the type of change rather than a definition of it.

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Section B: Core Practice

B1. Classify each process as a physical or a chemical change, justifying each answer at the particle level. (a) A block of dry ice, solid CO_2, left on a bench slowly disappears, forming cold CO_2 gas without ever becoming liquid. (b) An antacid tablet fizzes in stomach acid and carbon dioxide gas is released. (c) Nail polish remover evaporates from a cotton pad. (d) An iron bicycle chain left outside develops a flaky orange-brown coating. (e) Blue and yellow paints are stirred together and the mixture is green. (f) A drop of food colouring spreads through a glass of water until the colour is uniform.

B2. Use these values: the enthalpy of fusion of ice is 6.01 kJ/mol, the enthalpy of vaporisation of water is 40.7 kJ/mol, and the mean O-H bond enthalpy is 463 kJ/mol. (a) Calculate the energy needed to convert 1 mol of ice at 0 °C into steam at 100 °C, counting only the two phase changes. (b) Calculate the energy needed to break both O-H bonds in every molecule of 1 mol of water. (c) How many times larger is your answer to (b) than your answer to (a)? (d) Use your results to explain why melting and boiling are classified as physical changes.

B3. Two solids are stirred into separate beakers of water. In the first, sodium chloride disappears into the water and the solution conducts electricity. In the second, a piece of sodium fizzes violently, disappears, and hydrogen gas and sodium hydroxide are formed. (a) Describe the particle events in the first beaker. (b) Describe the particle events in the second beaker. (c) Classify each process and justify your answers. (d) The equation for the second process is $2Na + 2H_2O \rightarrow 2NaOH + H_2$. Verify that it balances by counting each kind of atom on both sides.

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B4. Separating 1 mol of sodium chloride lattice into isolated ions costs 787 kJ. Forming ion-dipole attractions between those ions and water releases 783 kJ. (a) Calculate the net enthalpy change when 1 mol of sodium chloride dissolves. (b) State whether the solution warms or cools slightly as the salt dissolves, and link your answer to (a). (c) Explain why this small net value neither makes dissolving chemical nor would a large value make it physical: what actually decides the classification? (d) Name the two opposing energy terms in the dissolving process, and state what each one corresponds to at the particle level.

B5. (a) Sugar stirred into hot tea disappears, and evaporating the tea leaves the sugar behind unchanged. Classify the dissolving and justify your answer. (b) An egg is fried: the clear, runny white sets into a white solid that cannot be made runny again by cooling. Classify the change and justify it at the particle level. (c) State the general reason the dissolving in (a) can be undone by a simple physical step while the change in (b) cannot. (d) A raw egg in its shell is left in vinegar. The shell fizzes and disappears, and carbon dioxide gas is produced. Classify the change to the shell and name the observation that signals it.

B6. A burning candle shows several changes at once. Solid wax near the flame melts. Liquid wax climbs the wick and turns to vapour. The vapour burns in air, forming carbon dioxide and water. (a) Identify the physical changes in this description and justify the classification. (b) Identify the chemical change and justify the classification. (c) A model equation for burning a fuel gas is $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. Verify the atom balance by counting carbon, hydrogen and oxygen on both sides. (d) State which stage of the candle process produces new substances, and what happens to the wax particles in the stages before it.

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Section C: Exam Style

C1. Two experiments are carried out. Experiment 1: two colourless solutions are mixed in a sealed flask. The mixture turns cloudy, a white solid settles at the bottom, and the temperature of the mixture rises by 3 °C. Experiment 2: a colourless liquid is heated in an open flask. It bubbles vigorously, and the vapour condenses on a cold surface back into the same liquid. (a) Classify the change in Experiment 1, citing two observations as evidence and justifying the classification at the particle level. (b) Classify the change in Experiment 2, and explain why the vigorous bubbles are not evidence of a chemical change. (c) State what the condensing vapour in Experiment 2 proves about the particles of the liquid. (d) The flask in Experiment 1 is sealed. State, with a reason, whether its total mass changes during the reaction.

C2. Photosynthesis in a leaf is summarised by $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$. At the same time, water vapour escapes from the leaf's pores, and on a cold night water vapour from the air condenses as dew on the leaf. (a) Verify that the equation balances by counting the atoms of each element on both sides. (b) Classify photosynthesis and justify your answer at the particle level. (c) Classify each of the other two processes in the stem, justifying each in one line. (d) Explain how physical and chemical changes can both proceed in the same leaf at the same time without any contradiction.

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C3. A student makes three claims. Evaluate each one. Claim 1: "Dissolving salt is a chemical change, because the crystal breaks apart and free ions appear in the solution." Claim 2: "Any change that releases heat must be a chemical change." Claim 3: "If a change can be reversed, it must be a physical change." (a) Evaluate Claim 1 at the particle level, stating whether it is correct. (b) Evaluate Claim 2, giving a counterexample of a heat-releasing change that is not chemical. (c) Evaluate Claim 3, giving one counterexample in each direction: a chemical change that can be reversed, and a physical change that in practice cannot.

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Answer Key

A1. (a) Whether the particles afterwards are the same substances as before, or whether the atoms have been regrouped into new substances. (b) Their spacing, their arrangement and their motion (equivalently, their state). The particles themselves, and so the substance, stay the same. (c) Bonds within the reactants break and new bonds form, regrouping the atoms into products. No atom is created, destroyed or turned into a different element. (d) Exactly the same elements, in the same total amounts; only the combinations of atoms have changed.

A2. (a) Physical. The H_2O molecules are unchanged; only their arrangement and spacing alter as vapour becomes solid. (b) Chemical. Bacteria convert milk sugars into new substances such as lactic acid, changing the taste and smell. (c) Physical. Liquid water becomes water vapour; the molecules are the same, only separated. (d) Chemical. Silver reacts with sulfur compounds in air to form silver sulfide, a new substance. (e) Physical. Every piece is still cellulose; only the size of the pieces changed.

A3. (a) Attractions between the molecules (the hydrogen bonds between neighbouring H_2O molecules); the bonds within each molecule are untouched. (b) Water vapour: H_2O molecules that have escaped the liquid as a gas, the same substance in its gas state. (c) A gas appearing is not necessarily a new substance. The gas here is the same H_2O molecules, merely separated and moving freely, so nothing new has formed and the change is physical. (d) The molecules themselves would have to break apart or rearrange, for example water splitting into hydrogen and oxygen, so different substances exist afterwards.

A4. (a) In the solid, Na^+ and Cl^- ions are locked in a regular lattice in a 1 to 1 ratio. In solution the same ions are separated, spread through the water, each surrounded by water molecules. (b) The ions after dissolving are exactly the ions the solid contained. Separating particles that already existed makes no new substance: no particle's composition changed, so the change is physical. (c) Evaporate the water. The salt crystallises out unchanged, showing the solution contained the same substance all along. (d) Sugar dissolves as whole, intact molecules spread among the water molecules, with no ions. The difference: the salt separates pre-existing ions from a lattice, while the sugar only separates whole molecules from each other.

A5. (a) A precipitate forming; a new gas produced; a colour change; a temperature change with no heating or cooling applied. An unexpected smell also counts. (b) Boiling water: the bubbles are the liquid's own vapour, the same substance changing state, not a gas generated by regrouping atoms. (c) The products may be colourless and dissolved, like the reactants, with a temperature change too small to notice: new substances, but no precipitate, gas or visible colour change. (d) The correlation fails in both directions: shattered glass is physical but cannot be reassembled in practice, while dehydrating blue copper(II) sulfate is chemical yet reverses when water is added back. The definition concerns new substances, not undoing.

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B1. (a) Physical. Solid CO_2 becomes CO_2 gas (sublimation); the molecules are identical throughout, only spacing and arrangement change. (b) Chemical. The acid reacts with the tablet's carbonate and generates carbon dioxide, a new substance; gas made by a reaction is new matter. (c) Physical. The liquid becomes a vapour; its molecules are unchanged and would condense back to the same liquid. (d) Chemical. Iron reacts with oxygen and water to form rust, hydrated iron(III) oxide, a new substance with different properties. (e) Physical. The pigments are mixed, not reacted; both are still present unchanged and the green is the mixture's combined appearance. (f) Physical. The colouring molecules spread intact among the water molecules; no new substance forms.

B2. (a) 6.01 + 40.7 = 46.71 kJ, about 46.7 kJ. (b) Two O-H bonds per molecule: 2 × 463 = 926 kJ. (c) 926 ÷ 46.71 = 19.8, about 20 times larger. (d) Both phase changes together spend about twenty times less energy than breaking the molecules' own bonds, and that energy goes only against attractions between molecules. The molecules emerge intact, so the substance is unchanged and the changes are physical.

B3. (a) The lattice separates: Na^+ and Cl^- ions leave the solid and spread through the water, each surrounded by water molecules, unchanged. It is these free ions that let the solution conduct. (b) Sodium atoms react with water molecules, producing Na^+ and OH^- ions in solution (sodium hydroxide) and hydrogen gas: atoms regrouped into substances not present before. (c) The salt dissolving is physical: the same ions exist before and after, only separated, and the salt is recoverable unchanged. The sodium process is chemical: new substances form, with bonds broken and made. (d) Sodium: 2 left, 2 right. Hydrogen: 2 × 2 = 4 left; 2 × 1 in the hydroxide plus 2 in H_2 = 4 right. Oxygen: 2 left, 2 × 1 = 2 right. Balanced.

B4. (a) 787 − 783 = +4 kJ per mole: dissolving absorbs a net 4 kJ per mole. (b) It cools slightly: the process takes a small net amount of energy from the water. The effect is tiny because the two large terms almost cancel. (c) Classification is decided by whether new substances form, not by energy size or sign. Dissolving moves large energies both ways yet forms nothing new, so it is physical; a change with a tiny energy change that regrouped atoms would still be chemical. (d) The cost term is separating the ions from the lattice, pulling each ion away from the oppositely charged ions holding it. The release term is hydration: ion-dipole attractions forming as water molecules cluster around each separated ion.

B5. (a) Physical. The sugar molecules spread intact among the water molecules; no internal bonds break and no new substance forms, confirmed by recovering identical sugar on evaporation. (b) Chemical. Heat permanently rearranges the protein structures into a set network, a different material with different properties; cooling cannot restore the original structures. (c) Dissolving altered only the separation of unchanged particles, so removing the water reverses the separation and restores the start. Cooking altered the particles' internal arrangements, and no simple physical step can rebuild them. (d) Chemical. The fizzing is the signal: carbon dioxide is a new gas generated as the acid reacts with the calcium carbonate shell, which is consumed into new substances.

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B6. (a) Melting and vaporising are physical: the wax particles stay the same molecules; only spacing, arrangement and motion change. (b) Burning the vapour is chemical: wax vapour and oxygen are regrouped into carbon dioxide and water, new substances. (c) Carbon: 1 left, 1 right. Hydrogen: 4 left, 2 × 2 = 4 right. Oxygen: 2 × 2 = 4 left; 2 in CO_2 plus 2 × 1 in the two H_2O = 4 right. Balanced. (d) Only the burning stage. Before it, the wax particles merely loosen, spread out and escape into the air as the same molecules.

C1. (a) Chemical. A white solid appears that was in neither colourless solution: dissolved particles have combined into a new insoluble substance, a precipitate. The 3 °C temperature rise, heat released as bonds rearrange, is supporting evidence. (b) Physical. The bubbles are the liquid's own vapour, the same substance in its gas state, produced by heating, not by regrouping atoms. (c) The vapour condenses back into exactly the liquid it came from, so its particles survived heating unchanged: the same molecules left and returned. (d) It stays the same. The flask is sealed, so no atoms enter or leave, and the reaction only regroups the atoms already inside; by conservation of mass the total cannot change.

C2. (a) Carbon: 6 left, 6 in the glucose. Hydrogen: 6 × 2 = 12 left, 12 in the glucose. Oxygen: 6 × 2 + 6 × 1 = 18 left; 6 in glucose plus 6 × 2 = 12 in the oxygen gas, 18 right. Balanced. (b) Chemical: carbon dioxide and water molecules are broken up and their atoms regrouped into glucose and oxygen, new substances with new properties. (c) Escaping water vapour is physical: liquid water becomes vapour, the same H_2O molecules separating. Dew condensing is physical: vapour becomes liquid water, the same molecules coming together. (d) Classification applies to each process, not to the object. The leaf's cells regroup atoms in photosynthesis while, independently, water molecules change state at its surfaces; one process being chemical says nothing about the other.

C3. (a) Incorrect. Na^+ and Cl^- already exist as ions inside the crystal lattice; dissolving does not create them. It separates them and surrounds each with water, changing no particle's identity and forming no new substance, so the salt is recoverable unchanged: a physical change. (b) Incorrect. Freezing water releases heat as liquid turns to ice, and condensing steam releases heat too, yet every H_2O molecule stays intact in both: heat release accompanies phase changes as well as reactions, so it cannot define a chemical change. (c) Incorrect in both directions. Heating blue hydrated copper(II) sulfate drives off its water to leave white anhydrous copper(II) sulfate, a chemical change, and adding water reverses it. Shattering a glass sheet is physical, the glass itself unchanged, yet the sheet cannot in practice be reassembled. Reversibility is a clue, never the test.

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