Metals and non-metals

Classifying elements by electrical conductivity and oxide character

YEAR 10 / LESSON 12 / CHEMISTRY + SCIENCE (DOUBLE AWARD)

The question

How can electrical conductivity and the acid-base character of oxides be used, as two kinds of evidence, to classify elements as metals or non-metals?

In this lesson you use two representative evidence sets. First you test a small set of solid elements — copper, magnesium, zinc, iron, sulfur and graphite — in a low-voltage series circuit. Then you add universal indicator to dilute, labelled stand-in solutions that illustrate the acid-base character of some soluble oxides in water. Those stand-in solutions are not "the oxides of the elements you have just tested": the two sets are distinct and overlap at sulfur only. A lamp that lights shows that the sample conducted in this circuit; it does not, by itself, prove that the sample is a metal, because graphite is a non-metal that also conducts. Record the colours and pH values you actually see. Iodine is a non-metal on the Periodic Table, but its conductivity is not tested in this class practical and must not be recorded as an observation.

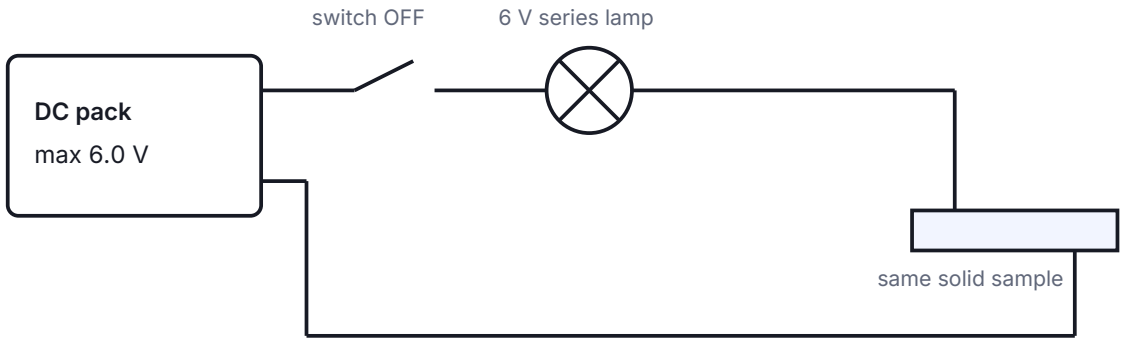
Course links: 1.20 — two representative evidence sets; 1.21 — related Periodic Table work, not a laboratory measurement. Insoluble and amphoteric oxides are not tested.

Wear splash-proof eye protection throughout. Read actual reagent labels; alkalis can seriously damage eyes. Wash skin splashes with plenty of water and tell the teacher at once. For an eye splash, rinse under running water as directed and tell the teacher immediately. Universal indicator may be alcohol-based and flammable: no flames. Avoid sulfur dust and sharp metal edges; use spatulas or tweezers. Do not taste. Follow the school's risk assessment.

Part A equipment • per group of up to three

Eye protection; maximum 6.0 V DC series-indicator tester, leads and clips/probes; separate labelled copper foil/sheet/wire, magnesium ribbon, zinc granule/strip (not powder), iron nail/strip, sulfur lump and graphite rod/2B lead, each with its own spatula or tweezers; clean tile or paper towel; spatula/emery paper; distilled-water wash bottle; paper towel; labelled solids recovery pot.

Maximum 6.0 V DC only; no mains. Use a 6 V lamp in series with the sample, or an LED with a suitable series resistor, so the circuit is current-limited. Keep the supply dry. Switch OFF before handling, moving or rinsing contacts. Use clean, dry contacts. Probes must not touch except for a brief lamp-tester function check.



Contacts about 1.0 cm apart; clips must not touch each other.

Part A • test the elements

Numbered method and actual observations

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Tester type and set potential (maximum 6.0 V DC), or meter identity:

1. Lamp-in-series tester ONLY: briefly touch probes together; the lamp should light, then go off when separated. If not, stop and tell your teacher. Record tester type and actual set potential (maximum 6.0 V DC). This is a function check, not weak-sample sensitivity. For a meter follow its own instructions, record its identity, and do not short probes or zero in air unless those instructions say so.

2. For copper, press both clips/probes firmly onto a clean part of the same piece, about 1.0 cm apart; they must not touch. Switch on if the pack has a switch. Record off/dim/bright OR meter reading and unit, then switch OFF. If off, scratch the surface and retest once. Keep both observations if they differ.

3. Repeat for magnesium, zinc and iron, switching off before moving the clips, and rinsing and drying or wiping the clips between samples.

4. For sulfur, press probes onto the same lump, 1.0 cm apart, without the probes touching. Record, switch off, return the lump.

5. For graphite, press probes onto the same rod or lead, 1.0 cm apart, record, switch off.

6. Enter each of the six tested elements, the container label (metal or non-metal), and the lamp or meter observation in Table A. Do not add a row for iodine, and do not write an iodine result as if it had been observed. Iodine may be mentioned only as a reference identity (a non-metal on the Periodic Table). Do not write a classification that treats Table A and Table B as paired results for the same element.

Table A • leave results blank until you test

Element	Metal / non-metal on container	Lamp off / dim / bright OR meter reading + unit	Contact / retest notes
Copper			
Magnesium			
Zinc			
Iron			
Sulfur			
Graphite			

Reference identity, NOT an observation: iodine is a non-metal on the Periodic Table. Its conductivity is not tested in this practical. Do not add an iodine result.

Part B • labelled stand-ins

Read the actual chemical identity, concentration and hazards

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Equipment • per group

Six clean 150 × 16 mm test tubes and a rack; 10 cm^3 measuring cylinder OR 5/10 cm^3 graduated pipette with a filler (fillers are for pipettes, not syringes); full-range universal indicator dropper and its matching pH chart; access to the six staff-issued stand-ins below; labelled waste beaker; sink and water for splashes.

Every handler must see the actual reagent identity, concentration and hazards on the working label. Teaching-purpose names must not hide these details. These liquids are staff-prepared stand-ins, not the oxides themselves; they were not made in class by reacting oxides with water.

Actual reagent	Concentration	Hazard and teaching-purpose information
Sodium hydroxide, NaOH(aq)	0.2 mol dm^{-3}	Irritant. Stand-in illustrating a soluble metal oxide in water; not sodium oxide.
Potassium hydroxide, KOH(aq)	0.2 mol dm^{-3}	Irritant. Stand-in illustrating a soluble metal oxide in water; not potassium oxide.
Limewater, saturated $Ca(OH)_2$(aq)	Saturated; much more dilute than 0.2 mol dm^{-3}	Treat as irritant. Stand-in illustrating a soluble metal oxide in water; not calcium oxide.
Sulfuric(VI) acid, H_2SO_4(aq)	0.2 mol dm^{-3}	Treat as potentially irritating, as labelled. Acidic stand-in; NOT the product of SO_2 and water.
Nitric(V) acid, HNO_3(aq)	0.2 mol dm^{-3}	Irritant. Acidic stand-in; NOT a verified generic nitrogen-oxide-and-water product.
Phosphoric(V) acid, H_3PO_4(aq)	0.2 mol dm^{-3}	Treat as potentially irritating, as labelled. Acidic stand-in; not made in class from phosphorus(V) oxide.

Limewater is more dilute than the sodium and potassium hydroxide stand-ins. This is a concentration difference, not a claim that calcium hydroxide is a weaker base. No particular indicator colour is guaranteed.

The conductivity set and stand-in set are distinct; sulfur is the only overlap. The sulfur-related liquid is an H_2SO_4 acidic stand-in, not an observed SO_2-and-water product.

Part B • method and results

Table B • six separate tubes; no invented colours or pH values

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1. Read and record each actual reagent name, concentration and hazard; record any teaching purpose. Label six clean dry tubes with the six actual reagent names on page 3.

2. Place 2.0 cm^3 of the first stand-in in its tube using a clean dry measuring device. Before changing solutions, use a clean dry device OR rinse with a little of the next solution and discard that rinse to waste. Never return unused solution to stock.

3. Add 3 drops of universal indicator. Mix by gentle swirling only; do not use a shared stirring rod.

4. Use the issued matching pH chart. Record actual colour, chart pH, and acidic/alkaline/neutral. If its bands differ from pH 1–6 / 7 / 8–14, follow that chart and note the difference. Do not assume a colour for limewater.

5. Repeat for the other five stand-ins, each in its own tube. Do not mix leftovers. Empty mixtures into labelled waste only when directed.

Actual reagent	Teaching purpose on label, if shown	Volume / cm^3	UI drops	Colour observed	Chart pH	Acidic / alkaline / neutral
NaOH(aq), 0.2 mol dm^{-3}						
KOH(aq), 0.2 mol dm^{-3}						
Limewater, saturated $Ca(OH)_2(aq)$						
$H_2SO_4(aq)$, 0.2 mol dm^{-3}						
$HNO_3(aq)$, 0.2 mol dm^{-3}						
$H_3PO_4(aq)$, 0.2 mol dm^{-3}						

Chart / unusual observations / any repeated reading:

Cleanup

Collect the six mixtures in labelled waste; return stock bottles as issued. Rinse glassware and measuring devices as directed. Return each solid to its own container, never the sink. Switch OFF, then rinse/dry contacts and disconnect as instructed. Wipe the bench, report splashes and wash hands.

Explain your evidence

Use your actual tables, not remembered or expected results

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1. For each solid element you actually tested, state whether it conducted in this circuit. Which result does not fit the simple rule 'only metals conduct'? Explain, in terms of structure, why graphite can conduct even though it is a non-metal.

2. The Part B bottles are staff-prepared stand-ins. Using the actual reagent names, what were you testing, and why does that still help you discuss the acid-base character of soluble oxides? Why must the sulfuric(VI) acid bottle not be described as 'the product of sulfur dioxide and water', and why must the nitric(V) acid bottle not be described as a verified generic nitrogen-oxide product?

3. Using Table B only, which stand-ins were alkaline and which were acidic, according to the colours and pH values you actually recorded? What does that suggest about metal oxides and non-metal oxides that react with water? Why can you not treat those conclusions as guaranteed colours, or as results for the oxides of the Table A elements?

Teacher demonstration • watch and record only

Watch copper/aluminium bending or flattening and heat travelling along a metal rod/strip with one end in hot water. Stand back; do not touch hot apparatus. What did you see? Keep these notes separate from Tables A and B: they are not the 1.20 classification tests.

Evaluate your conclusions

Two representative sets are not paired tests of the same element

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4. Why would it be unsound to classify an element as a metal using the conductivity test alone? Use graphite, and any other limitation you noticed, in your answer.

5. Some metal oxides do not react with water and would not change the pH of water even though they are still bases. Why can a neutral indicator colour therefore not be used, on its own, to decide that an oxide is not basic? (You did not test an insoluble oxide in this practical.)

6. The conductivity samples (Table A) and the oxide stand-in samples (Table B) are two representative evidence sets. They are not paired tests on the same elements. The only element that appears in both teaching sets is sulfur, and even then the sulfur-related liquid is 0.2 mol dm^{-3} sulfuric(VI) acid used as an acidic stand-in, not an observed product of sulfur dioxide and water. Using Table A, what do the conductivity results suggest, and what are their limits (include graphite)? Using Table B, what do the stand-in acid-base results suggest, and what are their limits? How can the two kinds of evidence, together with Periodic Table position, be used to classify elements as metals or non-metals without treating Table A and Table B as results for the same element? Do not add sodium or potassium metal to the conductivity set, and do not invent an iodine observation.

No graph is required. If asked for a pH bar chart, use only your own recorded chart readings and label actual reagents. Use the Periodic Table to relate classifications to element positions; this is reference work, not a new observation.

Sources: Pearson Edexcel International GCSE Chemistry (2017), 1.20–1.21; RSC / Nuffield, Testing the pH of oxides and Which substances conduct electricity?; CLEAPSS SSS031, SSS032 and SSS070. Follow your teacher's instructions and the school's risk assessment.