Structure 2.4 · From models to materials · supported focus

International Baccalaureate · IB Diploma · Chemistry · HL

Scope and prerequisites

Supported HL/SL core focus. First assessment 2025; current brief acquired; full Chemistry guide not acquired. Remaining guide, assessment and practical requirements retain their recorded holds.

Prerequisites: the ionic, covalent and metallic models from Structure 2.1–2.3, and density from earlier physical science. Each lesson develops its own method before independent transfer.

These are original or explicitly fictional teaching examples, not actual measurements or completed assessed learner investigations.

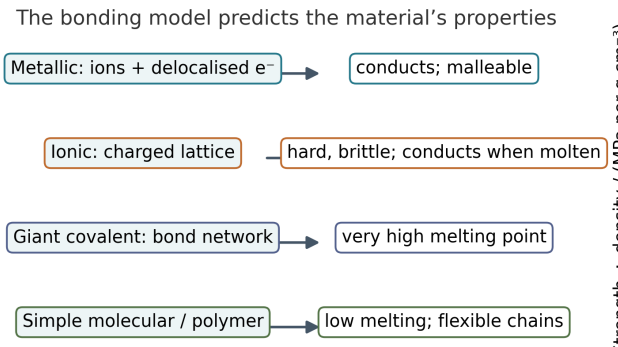
From models to materials

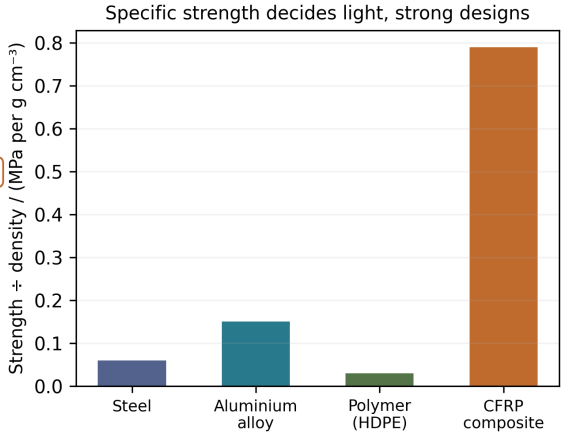
■ What would explain this observation?

- A copper wire bends without breaking and carries current; a ceramic plate snaps but never conducts; a plastic bag stretches and melts over a candle. Why do these materials behave so differently?
- Start with a prediction. State the quantities or features you would compare, then decide what evidence could distinguish two explanations.

■ Build the model

- The bonding model predicts the **bulk properties** : a **metallic material** has positive ions in a sea of delocalised electrons, so it conducts and is malleable. An ionic lattice is hard but brittle and conducts only when molten or dissolved. A giant covalent network has a very high melting point. Simple molecular substances and polymers melt low, and polymer chains can slide and flex.
- A **composite** combines materials so the product has properties neither part has alone, such as carbon fibres in a resin. Choosing a material means matching its model-derived properties to a design requirement, then checking measurable quantities such as strength, density and conductivity.
- bulk property: A measurable property of a material sample, such as strength or conductivity; composite: A material made of two or more components whose combined properties exceed the parts; metallic material: A material of metal ions held by delocalised electrons.





■ Choose evidence that can test it

- Test the model by measuring what it predicts: bend and stretch samples of a metal, an ionic solid and a polymer under the same conditions and compare conductivity in solid and molten states where the school permits. The model is supported only if the observed properties match the bonding in the structure.
- Compare candidate materials for one application using measured properties, not names: a bicycle frame needs high strength per unit mass, a window needs transparency and scratch resistance.

■ Work from known quantities

- State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution.
- Known: an aluminium alloy has strength 300 MPa and density 2.7 g/cm^3; a steel has strength 500 MPa and density 7.8 g/cm^3. The design needs strength per unit mass, so compute the ratio: alloy $300/2.7 \approx 111$ MPa per g/cm^3; steel $500/7.8 \approx 64$ MPa per g/cm^3. The alloy gives more strength for the same mass, so it suits a light frame even though the steel is stronger in absolute terms.

Example:

A carbon-fibre composite has strength 1,100 MPa at density 1.4 g/cm^3. Find its strength-to-density ratio and compare it with the alloy above, using the same sequence: known quantities → model → relation → substitution → unit and interpretation. (Answer: $1{,}100/1.4 \approx 786$ MPa per g/cm^3 – about seven times the alloy, which is why racing frames use it despite the cost.)

■ Check the conclusion and its limits

- A single ratio never settles a design choice: toughness, cost, corrosion resistance, manufacturability and end-of-life all matter. Bonding models describe ideal structures; real materials contain defects that lower measured strength below the model's prediction.
- Return to the original observation. Explain what the result supports, which conditions it assumes, and one way to test a competing explanation.

Warn:

The strongest material in absolute terms is always the best choice for a design. This claim is false: the best choice depends on the requirement – per unit mass the weaker-looking alloy beats the steel, and other criteria such as cost and corrosion can outweigh strength entirely.

Key:

From models to materials: bonding models predict bulk properties – metallic conducts and bends, ionic is hard and brittle, giant covalent resists heat, molecular and polymer materials melt low and flex. Material selection compares measured properties against a stated requirement, often as a ratio such as strength per density.