Course notes

International Baccalaureate · IB Diploma · Chemistry · HL

IB IB Diploma · Chemistry · HL: teaching notes

Version: First assessment 2025

These notes cover selected topics of the course; they are not the whole specification.

Assessment and course boundaries

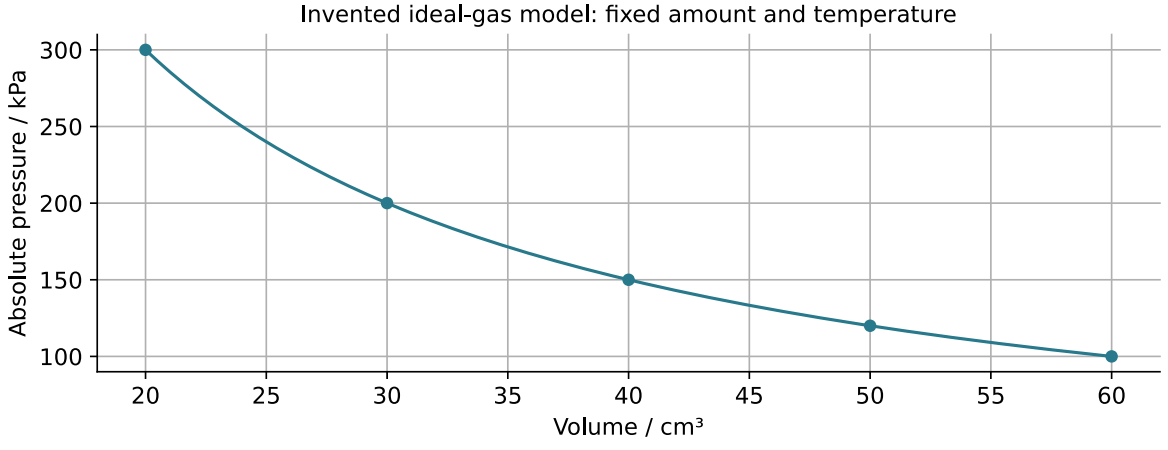
- Structure and reactivity replace the old topic/option model. Entropy and spontaneity is AHL; all other topics still require exact SL/AHL statement separation from the guide.
- Paper 1A MCQ + 1B experimental/data work, Paper 2 short/extended responses; SL 1.5/1.5 h, HL 2/2.5 h; weights 36%/44%. Scientific investigation 20%, 3,000 words.
- Practical work 40 h plus collaborative sciences project 10 h and investigation 10 h; use the current chemistry data booklet.

Gas models and absolute temperature

Official-unit focus: Structure 1.1 Introduction to the particulate nature of matter; Structure 1.5 Ideal gases

A sealed gas container changes pressure when heated. Celsius ratios cannot predict the pressure change because the gas model uses absolute temperature.

In a gas model, particles move randomly and pressure results from momentum transfer at walls. The ideal gas equation connects pressure, volume, amount and absolute temperature.



At fixed amount and volume, pressure is proportional to kelvin temperature. At fixed

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temperature and amount, pressure is inversely proportional to volume. State which quantities are fixed before choosing a relationship.

Use approved apparatus with a temperature range and pressure limit set by the teacher. Allow thermal equilibrium and record pressure against kelvin temperature. Never heat an improvised sealed vessel.

■ Checked worked case

Known: pressure is 100 kPa at 300 K, with fixed volume and amount. At 330 K, p2/p1=T2/T1. p2=p1 T2/T1=100×330/300=110 kPa. A 30 °C rise is a 30 K change, but the temperature ratio must use kelvin.

■ Common error

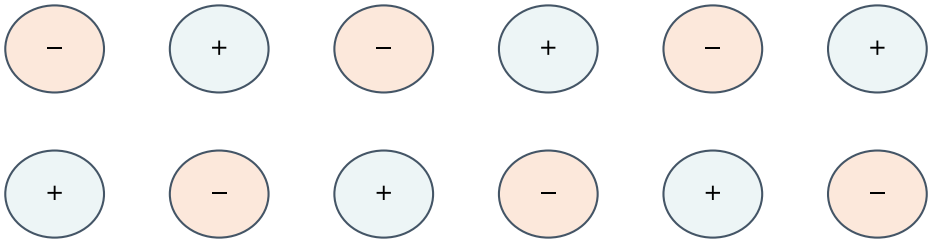
An ideal gas is a model with conditions of validity. Celsius zero is not zero molecular motion, and internal energy is not determined by pressure alone.

Particles, bonding and bulk properties

Official-unit focus: Structure 1.2 The nuclear atom; Structure 1.3 Electron configurations; Structure 2.1 The ionic model; Structure 2.2 The covalent model; Structure 2.3 The metallic model; Structure 2.4 From models to materials; Structure 3.1 The periodic table: classification of elements

A salt crystal conducts when dissolved but not when solid. The ions exist in both states; their ability to move changes.

Ionic bonding is electrostatic attraction between oppositely charged ions. A covalent bond involves shared electrons. Metallic bonding involves attraction between positive metal ions and delocalized electrons.



Alternating charges in an ionic lattice

To explain a bulk property, name the structure, particles, forces and mobile charge carriers. Simple molecular substances can have strong covalent bonds inside molecules but weak attractions between molecules.

Compare substances using evidence such as melting point, conductivity when solid

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and molten, and solubility. One property rarely proves a structure; use a pattern of evidence.

■ Checked worked case

Known: an element has atomic number 12 and mass number 24. Protons = 12; neutrons = mass number - atomic number = 24 - 12 = 12. A 2+ ion has electrons = 12 - 2 = 10. Charge changes electron count, not the nucleus.

■ Common error

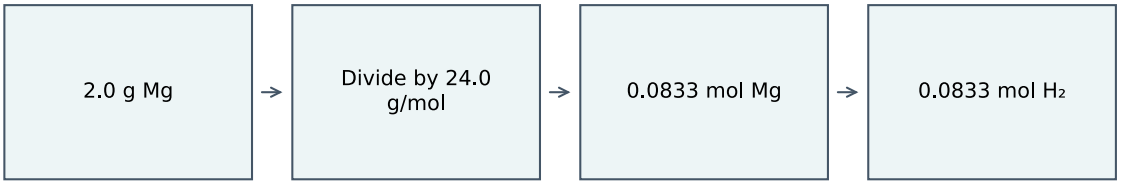
Melting a simple molecular substance usually overcomes intermolecular attractions; it does not require breaking all covalent bonds within each molecule.

Amounts, equations and limiting reagents

Official-unit focus: Structure 1.4 Counting particles by mass: the mole; Reactivity 2.1 How much? The amount of chemical change

The smallest mass of reactant is not necessarily the limiting reagent. The balanced equation compares particle amounts, not grams directly.

The mole measures amount of substance. Use molar mass to convert mass into amount. Balanced equation coefficients give mole ratios; they do not give equal masses.



Calculate the amount available for each reactant and divide by its coefficient. The smaller ratio limits the reaction. Use that reactant to calculate the maximum product before comparing actual yield.

Write the balanced equation first, include units in molar masses, then convert each given mass or solution volume into amount. Convert cubic centimetres to cubic decimetres before using concentration in moles per cubic decimetre.

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■ Checked worked case

Known: 2.0 g of Mg reacts with excess acid. Use amount = mass/molar mass. With molar mass Mg = 24.0 g per mole, amount Mg = 2.0/24.0 = 0.0833 mol. In Mg + 2HCl → MgCl2 + H2, amount H2 = amount Mg = 0.0833 mol.

■ Common error

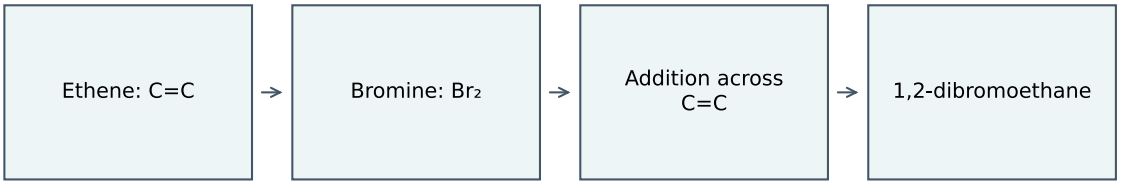
Excess acid means acid does not limit the stated calculation. A coefficient of 2 before HCl does not double the hydrogen amount.

Organic structures and reaction pathways

Official-unit focus: Structure 3.2 Functional groups: classification of organic compounds; Reactivity 3.3 Electron sharing reactions; Reactivity 3.4 Electron-pair sharing reactions

Two compounds can have the same molecular formula but different structures. Their functional groups help predict which reactions they undergo.

A homologous series shares a functional group and general formula. Structural isomers share a molecular formula but differ in atom connections. Alkenes contain a carbon-carbon double bond.



Distinguish addition, substitution, oxidation and polymerization by tracing bonds before and after reaction. Conditions and reagents belong to the reaction arrow; they are not interchangeable labels.

Draw displayed or structural formulae with the correct number of bonds at each carbon. Use a carbon count to check a proposed synthesis. At advanced level, track reagents and conditions through multistep routes.

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■ Checked worked case

Known: ethene adds bromine across its double bond. The two-carbon skeleton stays intact and each carbon gains one bromine atom, giving 1,2-dibromoethane. One mole of ethene reacts with one mole of bromine in this addition reaction.

■ Common error

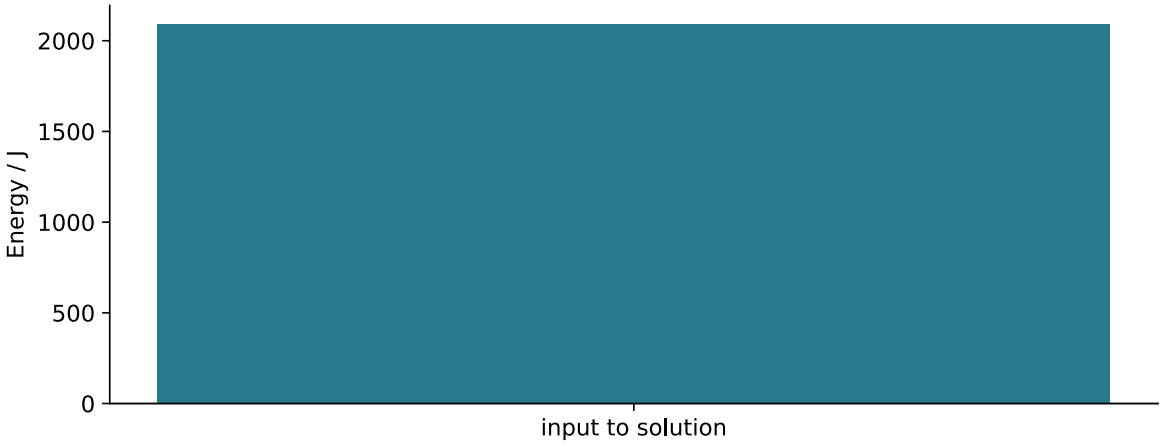
Bromine decolourization provides evidence of unsaturation in an appropriate test. It is not proof that an unknown sample is specifically ethene.

Calorimetry and chemical energy

Official-unit focus: Reactivity 1.1 Measuring enthalpy change; Reactivity 1.2 Energy cycles in reactions

A cup warms when two solutions react. The temperature rise measures energy transferred to the surroundings; it does not directly equal the enthalpy change.

Exothermic reactions transfer energy to surroundings. Endothermic reactions take energy from surroundings. Bond breaking requires energy; bond formation releases energy.



Use energy transferred = mass × specific heat capacity × temperature change. Convert joules to kilojoules before dividing by reaction amount. An exothermic molar enthalpy change has a negative sign.

Use insulation and a lid, measure starting temperatures consistently, stir, and record a temperature-time series. Estimate the reaction temperature from an appropriate extrapolation rather than ignoring cooling during measurement.

■ Checked worked case

Known: 100 g solution rises by 5.0 °C; specific heat capacity is 4.18 J per gram per degree. q = mcΔT. q = 100 × 4.18 × 5.0 = 2,090 J = 2.09 kJ. If 0.050 mol reacts, ΔH = -q/n = -2.09/0.050 = -41.8 kJ per mole.

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■ Common error

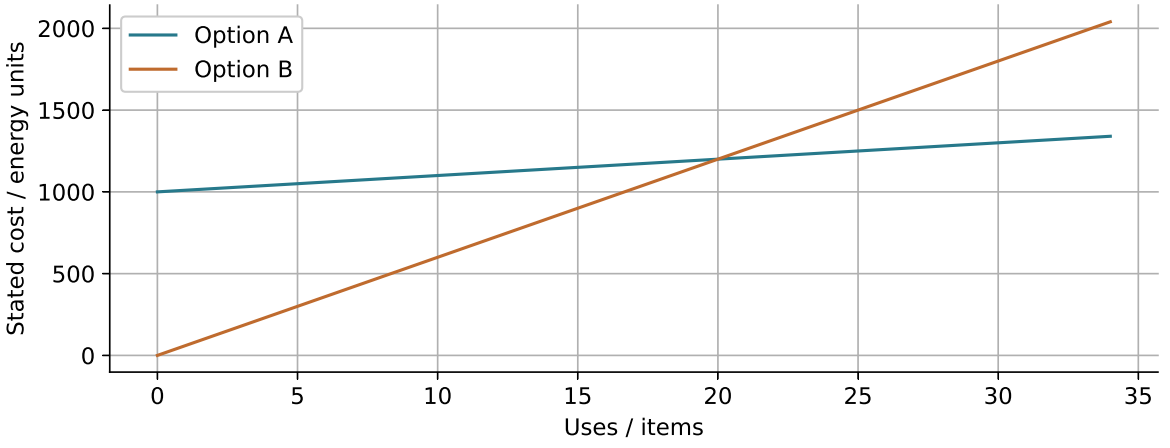
Heat loss usually lowers the observed temperature rise. The solution gaining heat and the reaction losing heat have opposite signs.

Atmosphere, resources and life-cycle decisions

Official-unit focus: Reactivity 1.3 Energy from fuels

A reusable container can require more energy to manufacture than a single-use one. Its impact depends on how often it is used and what happens at disposal.

A life-cycle assessment considers raw materials, manufacture, transport, use and end-of-life processes. Greenhouse gases absorb and emit infrared radiation; pollution and climate effects are related but distinct questions.



Define the functional unit before comparing products. The same delivered service, such as carrying one litre of water a hundred times, is fairer than comparing one object with another regardless of lifetime.

List system boundaries, energy sources and assumptions. Compare water demand, emissions and waste separately before making a judgement. Explain whose priorities affect the decision and where the data are uncertain.

■ Checked worked case

Known: a reusable item requires 1,000 energy units to make and 10 per use; a disposable item requires 60 per use. Equality occurs when $1{,}000 + 10n = 60n$. Rearranging gives $1{,}000 = 50n$, so $n = 20$ uses under this simplified model.

■ Common error

A break-even model is sensitive to cleaning, transport and disposal assumptions. Recyclable does not guarantee that an item is actually collected and recycled.

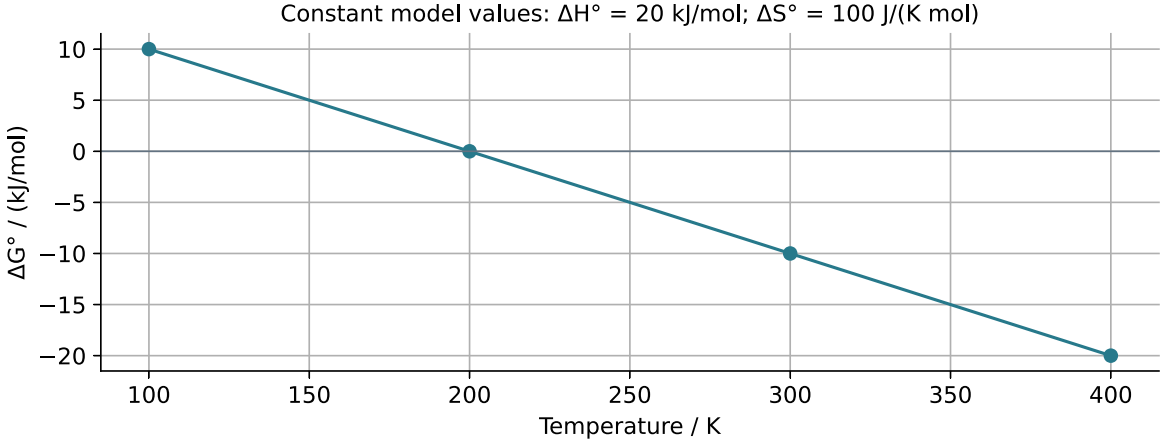
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Entropy, Gibbs energy and feasibility

Official-unit focus: Reactivity 1.4 Entropy and spontaneity

A reaction can be endothermic and still be thermodynamically favourable. Enthalpy alone does not determine the direction favoured at a given temperature.

Entropy is associated with energy dispersal and the number of accessible microscopic arrangements. Gibbs energy combines enthalpy, entropy and absolute temperature for a process at constant temperature and pressure.



Use $\Delta G = \Delta H - T\Delta S$ with consistent energy units. A negative Gibbs energy change indicates thermodynamic favourability for the stated conditions, not a fast rate. An activation barrier can make a favourable process slow.

State whether values are standard-state quantities and record temperature in kelvin. Convert entropy from joules per kelvin per mole into kilojoules per kelvin per mole when enthalpy is in kilojoules per mole.

■ Checked worked case

Known: $\Delta H = +20$ kJ per mole, $\Delta S = +100$ J per kelvin per mole and $T = 300$ K. Convert $\Delta S = 0.100$ kJ per kelvin per mole. $\Delta G = \Delta H - T\Delta S = 20 - 300 \times 0.100 = -10$ kJ per mole. The process is favourable under the stated approximation.

■ Common error

Thermodynamic favourability does not establish reaction rate. Celsius cannot replace kelvin in $T\Delta S$, and a unit conversion error can change the result by a factor of 1,000.

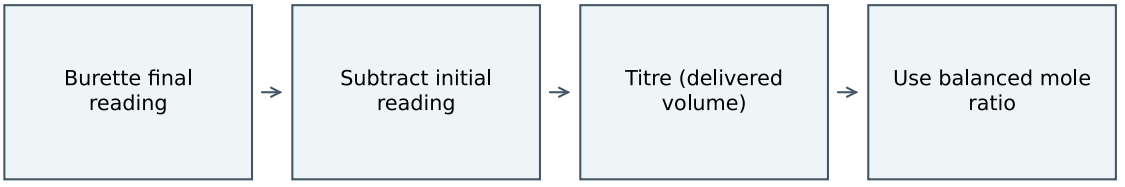
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Titration and a defensible concentration

Official-unit focus: Reactivity 2.1 How much? The amount of chemical change; Reactivity 3.1 Proton transfer reactions

A burette reading is not the delivered volume. The titre is the difference between final and initial readings, and both readings have uncertainty.

A titration measures the amount of one solution needed to react with a known amount of another. The equation gives the mole ratio. An indicator endpoint approximates the equivalence point when a suitable indicator is used.



Calculate the known amount first, apply the stoichiometric ratio, then divide by the unknown solution volume in cubic decimetres. Use concordant titres as required by the school method and report the accepted values.

Rinse the burette with its solution and the pipette with the solution it transfers. Rinse the flask with distilled water. Add titrant slowly near the endpoint, swirl, and read the meniscus at eye level. Use a white tile and appropriate eye protection.

■ Checked worked case

Known: 25.0 cubic centimetres of acid reacts 1:1 with 20.0 cubic centimetres of 0.100 mol per cubic decimetre alkali. $n = cV = 0.100 \times 0.0200 = 0.00200$ mol. Acid amount is 0.00200 mol. $c = n/V = 0.00200/0.0250 = 0.0800$ mol per cubic decimetre.

■ Common error

Adding distilled water to the flask changes volume but not the transferred amount of analyte. Do not average a rough titre with carefully measured concordant values.

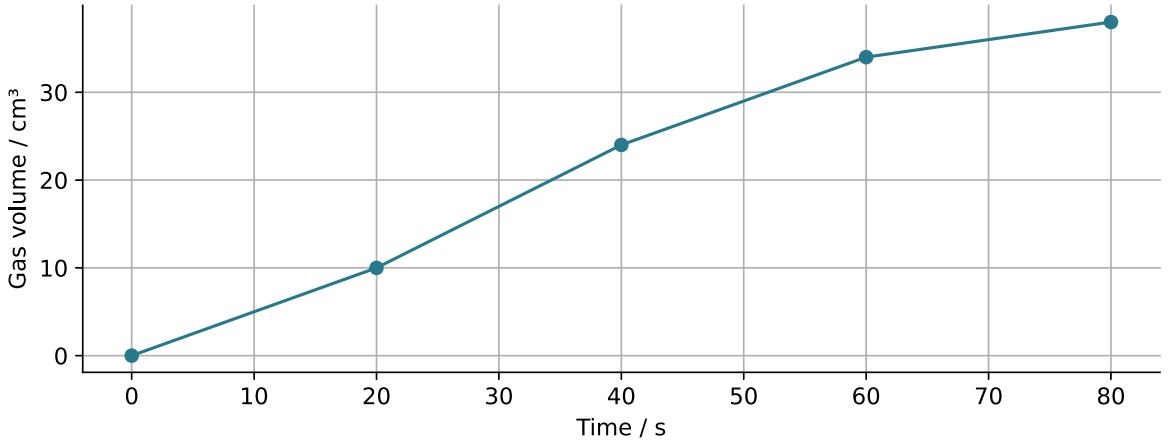
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Rates, catalysts and reliable endpoints

Official-unit focus: Reactivity 2.2 How fast? The rate of chemical change

A faster reaction finishes sooner, but it need not make more product. Rate and final yield answer different questions.

Reaction rate describes reactant used or product formed per time. Higher temperature increases the fraction of collisions with enough energy. A catalyst provides an alternative pathway with lower activation energy.



A product-time graph has a steeper gradient where rate is larger. A tangent estimates instantaneous rate; a secant gives average rate over an interval. The final plateau reflects the total collected product under the stated conditions.

For gas production, check apparatus for leaks, start timing consistently and record volume at regular intervals. Keep concentration, reactant amount and surface area controlled when changing temperature.

■ Checked worked case

Known: gas volume increases from 10 to 34 cubic centimetres between 20 and 60 s. Average rate = change in volume/change in time. Rate = (34 - 10)/(60 - 20) = 0.60 cubic centimetres per second. This is not necessarily the instantaneous rate at 40 s.

■ Common error

A catalyst does not change the equilibrium constant at a fixed temperature. A mass-loss method cannot detect all reactions, and losing gas through a leak biases a collection experiment.

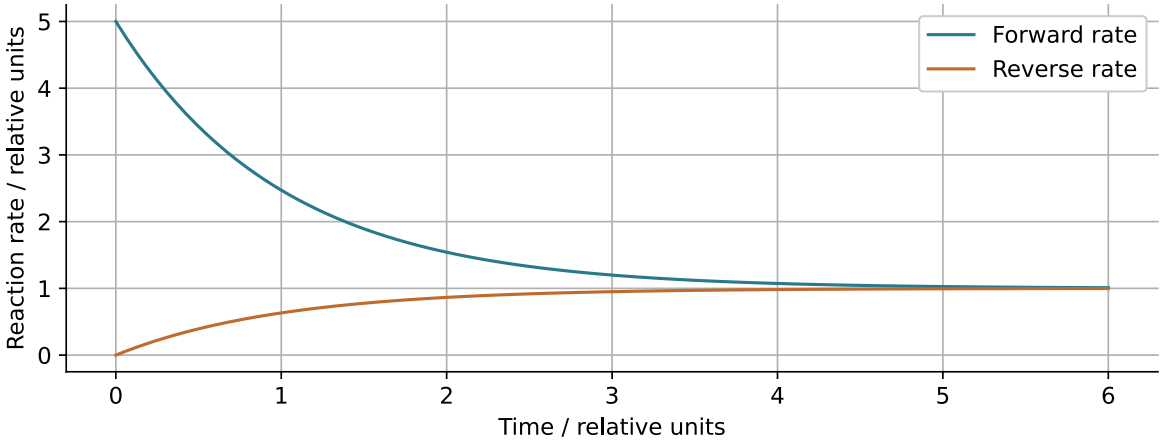
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Equilibrium and changing conditions

Official-unit focus: Reactivity 2.3 How far? The extent of chemical change

A reversible reaction can continue in a closed vessel while measured concentrations stay constant. Constant composition does not mean particles have stopped reacting.

Dynamic equilibrium occurs in a closed system when forward and reverse rates are equal. Reactant and product concentrations are constant, but they need not be equal.



A concentration or pressure change disturbs the balance. The system responds toward a new equilibrium. Temperature changes can also change the equilibrium constant; a catalyst changes how quickly equilibrium is reached.

State the balanced equation and whether the forward reaction is exothermic before predicting a temperature effect. Count gas coefficients when considering pressure; pressure has no composition effect when gaseous amounts are equal on both sides.

■ Checked worked case

Known: in $A \rightleftharpoons B$, equilibrium concentrations are $[A] = 0.20$ and $[B] = 0.60$ in the same concentration unit. For this stated expression, $K = [B]/[A]$. $K = 0.60/0.20 = 3.0$. Equal rates do not imply $K = 1$.

■ Common error

Do not use a catalyst to claim a larger equilibrium yield. For heterogeneous equilibria, pure solids are omitted from the usual equilibrium expression.

Redox and electrolysis

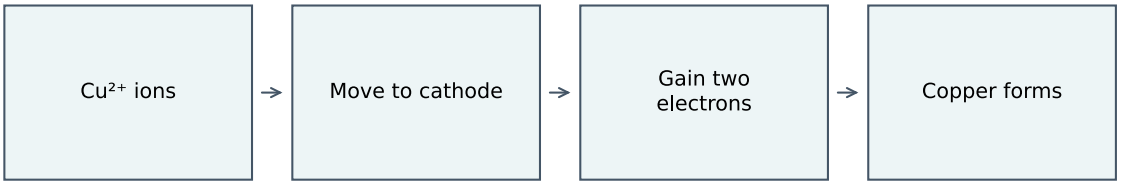
Official-unit focus: Reactivity 3.2 Electron transfer reactions

An aqueous salt solution can produce different electrode products from the molten salt. Water introduces competing species into the system.

Oxidation is loss of electrons and reduction is gain of electrons. In electrolysis, cations move toward the cathode and anions toward the anode. Reduction occurs at the

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cathode.



Predict products using the specified electrolyte and electrode material. In an aqueous solution, hydrogen or oxygen may form because water-related species compete. Molten salts contain only the ions of the salt.

Use a low-voltage direct-current supply, approved electrodes, and the school risk assessment. Collect gases only by an approved method. Keep chlorine demonstrations teacher-controlled; do not ask students to generate hazardous gases independently.

■ Checked worked case

Known: a copper ion gains two electrons. Half-equation: $Cu^{2+} + 2e^- \rightarrow Cu$. One mole of Cu^{2+} requires two moles of electrons. For 0.050 mol of copper, electron amount $= 2 \times 0.050 = 0.100$ mol.

■ Common error

Electrode signs depend on the cell type. In an electrolytic cell the cathode is negative; reduction remains the defining process at a cathode in every cell.

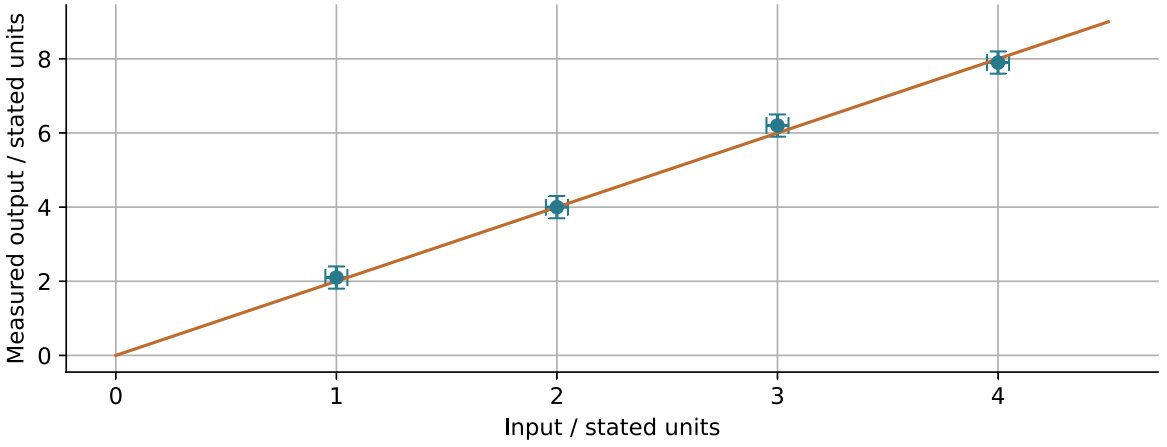
Uncertainty, gradients and model testing

Official-unit focus: Practical Experimental programme

A line passing near every data point is useful, but its gradient can still be uncertain. A graph is evidence for a model within the measurement range.

Random variation makes repeated readings differ. Systematic error shifts results consistently. Absolute uncertainty has the measured unit; relative or percentage uncertainty compares uncertainty with the measured value.

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For a product or quotient, adding fractional uncertainties is a common maximum-uncertainty approximation. For a difference, add absolute uncertainties. A nonzero intercept can reveal an offset or an incomplete model.

Show units on axes and choose a sensible scale. Plot uncertainty bars where justified, draw a best-fit line rather than joining every point, and estimate steepest and shallowest plausible gradients when the course method calls for them.

■ Checked worked case

Known: length = 50.0 mm with uncertainty 1.0 mm. Percentage uncertainty = absolute uncertainty/value $\times 100 = 1.0/50.0 \times 100 = 2.0\%$. For a quotient of two independently measured quantities with maximum percentage uncertainties 2% and 3%, the summed maximum estimate is 5%.

■ Common error

Repeating readings reduces random uncertainty in a mean but does not automatically remove a zero error. Do not quote more decimal places than your measurement can support.

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