STUDY FORMULA BOOKLET

Edexcel IAL Chemistry Unit 5 (WCH15): transition metals and organic nitrogen chemistry

The data booklet for Unit 5 gives electrode potentials, constants and spectroscopy tables but no equations. Learn Ecell = E(right) - E(left), the titration, yield and percentage uncertainty working; the Nernst equation was printed both times it was needed.

GIVEN in the data booklet LEARN IT not in the booklet: learn it

Built by CuratedPrep from 21 past question papers for Unit 5 in our question bank, June 2019 to January 2026. Given means it is in the data booklet handed out for Units 2, 4 and 5. Learn it means a past question needed it and the exam did not print it.

Data booklet constants

The data booklet is issued for Unit 5. These are the constants from it that the papers needed.

Gas constant (R)

Take 8.31 from the booklet. Oct 2025 Q5(b) printed it as well. Used in: Jun 2020 Q21(c), Nernst equation at 298 K; Oct 2025 Q5(b), K from Ecell.

$$R = 8.31\ \text{J mol}^{-1}\,\text{K}^{-1}$$

GIVEN

Avogadro constant (L)

Multiply the amount in mol by L to count particles. Used in: Oct 2025 Q14(a), molecules of carminic acid per insect; Oct 2024 Q15(b), which also printed L.

$$L = 6.02 \times 10^{23}\ \text{mol}^{-1}$$

GIVEN

Molar volume of a gas at room temperature and pressure (r.t.p.)

The molar volume at r.t.p. Jan 2025 Q13 and Jan 2023 Q20 printed it as well. Used in: Jun 2024 Q19, 95.6 dm^3 of carbon dioxide; Jan 2025 Q13; Jan 2023 Q20.

$$V_\text{m} = 24\ \text{dm}^3\,\text{mol}^{-1}$$

GIVEN

Volume conversion

Convert cm^3 of a titre to dm^3 before using c x V. Used in: Jun 2022 Q15(a)(iii), titre in cm^3; Jan 2026 (A) Q18(a)(ii).

$$1\ \text{dm}^3 = 1000\ \text{cm}^3 = 0.001\ \text{m}^3$$

GIVEN

Redox equilibria and electrode potentials

Take electrode potentials from the table in the data booklet, which lists reductions. The equations that join Ecell to entropy and K were printed when they were needed.

Standard emf of a cell

The positive electrode is the one with the more positive E. Rearrange to find an unknown half-cell value, and do not multiply E by the number of electrons. Used in: Jan 2026 Q2, silver and copper cell; Jan 2026 (A) Q1(a), a half-cell value from a given emf; Oct 2019 Q20(b)(ii).

$$E^\ominus_\text{cell} = E^\ominus_\text{right} - E^\ominus_\text{left}$$

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Cell diagram

The oxidised form of each half-cell sits next to the salt bridge, and an ion/ion half-cell needs a Pt electrode. Used in: Jan 2026 Q22(a), peroxodisulfate and iodide; Jan 2026 (A) Q3, iron and tin; Jun 2024 Q5.

$$\text{Pt}\,|\,\text{Fe}^{2+}, \text{Fe}^{3+}\,||\,\text{Ag}^{+}\,|\,\text{Ag}$$

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Ecell, total entropy change and equilibrium constant

The specification says Ecell is directly proportional to ΔStotal and to ln K (16.11). A positive Ecell means a positive ΔStotal, K above 1 and a thermodynamically feasible reaction. Oct 2025 Q5 printed the full equations with F and R. Used in: Jan 2026 Q22(b)(iii); Jan 2025 Q8; Jan 2024 Q1.

$$E^{\ominus}_{\text{cell}} \propto \Delta S_{\text{total}} \quad \text{and} \quad E^{\ominus}_{\text{cell}} \propto \ln K$$

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Ecell and total entropy change

Not on the sheet: the question printed it. n is the number of electrons transferred and T is in kelvin; using °Celsius was the distractor. Used in: Oct 2025 Q5(a), zinc and hydrogen ions; Oct 2025 (A) Q5(a).

$$E^{\ominus}_{\text{cell}} = \frac{T\,\Delta S_{\text{total}}}{nF}$$

GIVEN

Ecell and the equilibrium constant

Not on the sheet: the question printed it. Take the exponential of the result to get K. Use R = 8.31 J mol^{-1} K^{-1} and T in kelvin. Used in: Oct 2025 Q5(b), iron(III) and iodide ions; Oct 2025 (A) Q5(b).

$$\ln K = \frac{nFE^{\ominus}_{\text{cell}}}{RT}$$

GIVEN

Nernst equation

Not on the sheet: the question printed it. n is the number of electrons in the half-equation, with T in kelvin. Jun 2022 Q17 printed it as E = E(standard) + (0.0260 / z) ln[ion] with z the charge on the ion, and Jun 2020 Q21 printed the RT / (96 500 x n) form. Used in: Jun 2022 Q17(d)(ii), concentration of zinc ions from an emf; Jun 2020 Q21(c), chromium(III) at 0.0100 mol dm^{-3}.

$$E = E^{\ominus} + \frac{RT}{nF}\ln[\text{ion}]$$

GIVEN

Faraday constant

Not on the sheet: the question printed it. It is not in the data booklet; the question gave it in each case. Used in: Oct 2025 Q5(a); Jun 2020 Q21(c).

$$F = 96\,500\ \text{C mol}^{-1}$$

GIVEN

Redox titrations, amounts and uncertainty

Amount from mass

Use molar masses worked out from the periodic table unless the question gives them. Used in: Jan 2026 Q21(a), cerium(IV) sulfate; Jan 2026 (A) Q4(b), mass of Cr2(SO4)3.18H2O; Jun 2022 Q17(a)(i).

$$n = \frac{m}{M}$$

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Concentration

For a volume in cm^3 use n = c x V / 1000. Used in: Jan 2026 (A) Q18(a)(ii), moles of manganate(VII); Jun 2025 Q2(b); Jan 2026 Q21(a).

$$c = \frac{n}{V}$$

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Titration

Write the equation ratio first (1 MnO4- to 5 Fe2+, 1 Cr2O7 2- to 6 Fe2+), then scale a 25.0 cm^3 sample up to the 250.0 cm^3 flask. Used in: Jan 2026 (A) Q18(a)(ii); Jun 2022 Q15(a)(iii); Oct 2019 Q21(e)(ii), iodine and thiosulfate.

$$n(\text{A}) = \frac{\text{coefficient of A}}{\text{coefficient of B}} \times n(\text{B})$$

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Percentage by mass

For an element in a compound the mass of the component is n x Ar in one mole and the total is Mr. Used in: Jun 2022 Q15(a)(iii), potassium dichromate(VI) in cement; Oct 2019 Q21(e)(ii), copper in brass; Jun 2022 Q7(a), carbon in a polymer repeat unit.

$$\%\ \text{by mass} = \frac{\text{mass of component}}{\text{total mass}} \times 100$$

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Number of particles

Convert a mass or a limit to moles first. Used in: Oct 2025 Q14(a); Oct 2024 Q15(b), 15 mg m^{-3} of butylamine.

$$N = n \times L$$

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Amount of a gas at r.t.p.

V in dm^3, using the printed molar volume. Used in: Jun 2024 Q19; Jan 2025 Q13, 5.8 g of butane; Jan 2023 Q20.

$$n = \frac{V}{24}$$

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Parts per million

Parts per billion uses 10^9 instead of 10^6. Used in: Jan 2023 Q10, 405 ppm in 250 cm^3 of air; Jan 2025 Q20, chromium(III) in blood; Oct 2025 Q14.

$$\text{ppm} = \frac{\text{mass of component}}{\text{total mass}} \times 10^6$$

LEARN IT

Mass, density and volume

The question prints the density; you supply the relationship, with volume in cm^3 for a density in g cm^{-3}. Used in: Jan 2024 Q14(d), volume of benzene; Jun 2022 Q12(f); Jun 2024 Q19, glycerol.

$$m = \rho V$$

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Percentage uncertainty

A titre is two burette readings, so double the single-reading uncertainty unless the question gives the total; a balance used twice is treated the same way. Used in: Jan 2026 (A) Q18(b); Jun 2025 Q2(c), a titre of 18.95 cm^3; Jun 2022 Q6.

$$\%\ \text{uncertainty} = \frac{\text{uncertainty in the measurement}}{\text{value measured}} \times 100$$

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Benzene and its stability

Stabilisation energy of benzene

Both enthalpies of hydrogenation are negative. Benzene's is less exothermic by the stabilisation energy, 152 kJ mol^{-1} with the values -208 and 3 x -120. Used in: Jan 2026 Q19; Jun 2023 Q23; Jan 2024 Q13(c).

$$\Delta H_{\text{Kekulé}} = 3 \times \Delta H_{\text{hyd}}(\text{cyclohexene}), \quad \text{stabilisation} = \Delta H_{\text{hyd}}(\text{benzene}) - \Delta H_{\text{Kekulé}}$$

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Synthesis, yield and formulae

Percentage yield

Compare moles with moles or mass with mass; rearrange it to find a starting mass from a product mass and a yield. Used in: Jan 2026 Q18(a)(ii), isomer 1 from methoxybenzene; Oct 2024 Q6, 1-nitronaphthalene; Jun 2022 Q12(f).

$$\%\ \text{yield} = \frac{\text{actual amount of product}}{\text{theoretical amount of product}} \times 100$$

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Overall yield of a multi-step synthesis

Multiply the step yields as fractions (70% and 60% give 0.42), then apply that to the theoretical mass; never add them. Used in: Jan 2026 (A) Q14, benzene to phenylamine; Jan 2025 Q11, phenol to aspirin; Oct 2019 Q19.

$$\text{overall yield} = y_1 \times y_2 \times \cdots$$

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Percentage atom economy

Divide by the sum of the molar masses of all the products in the balanced equation. Used in: Oct 2024 Q9, the cumene process; Jun 2024 Q9(a), which printed the molar masses including HBr.

$$\%\ \text{atom economy} = \frac{\text{molar mass of the desired product}}{\text{sum of the molar masses of all products}} \times 100$$

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Mass of carbon and hydrogen in a combustion analysis Oxygen is the sample mass minus these two. Divide each mass by its Ar, then by the smallest result, to get the empirical formula. Used in: Oct 2025 Q11(a); Jun 2022 Q14(a), cinnamon oil compound; Jan 2026 Q16.	$m(\mathrm{C}) = m(\mathrm{CO_2}) \times \frac{12}{44}, \quad m(\mathrm{H}) = m(\mathrm{H_2O}) \times \frac{2}{18}$	LEARN IT
Molecular formula from the empirical formula Take Mr from the mass spectrum or the question. Used in: Oct 2019 Q24(f)(ii), raspberry ketone with Mr 164; Jun 2019 Q19(a).	$\text{molecular formula} = (\text{empirical formula}) \times \frac{M_\mathrm{r}}{\text{empirical formula mass}}$	LEARN IT

Standard electrode potentials

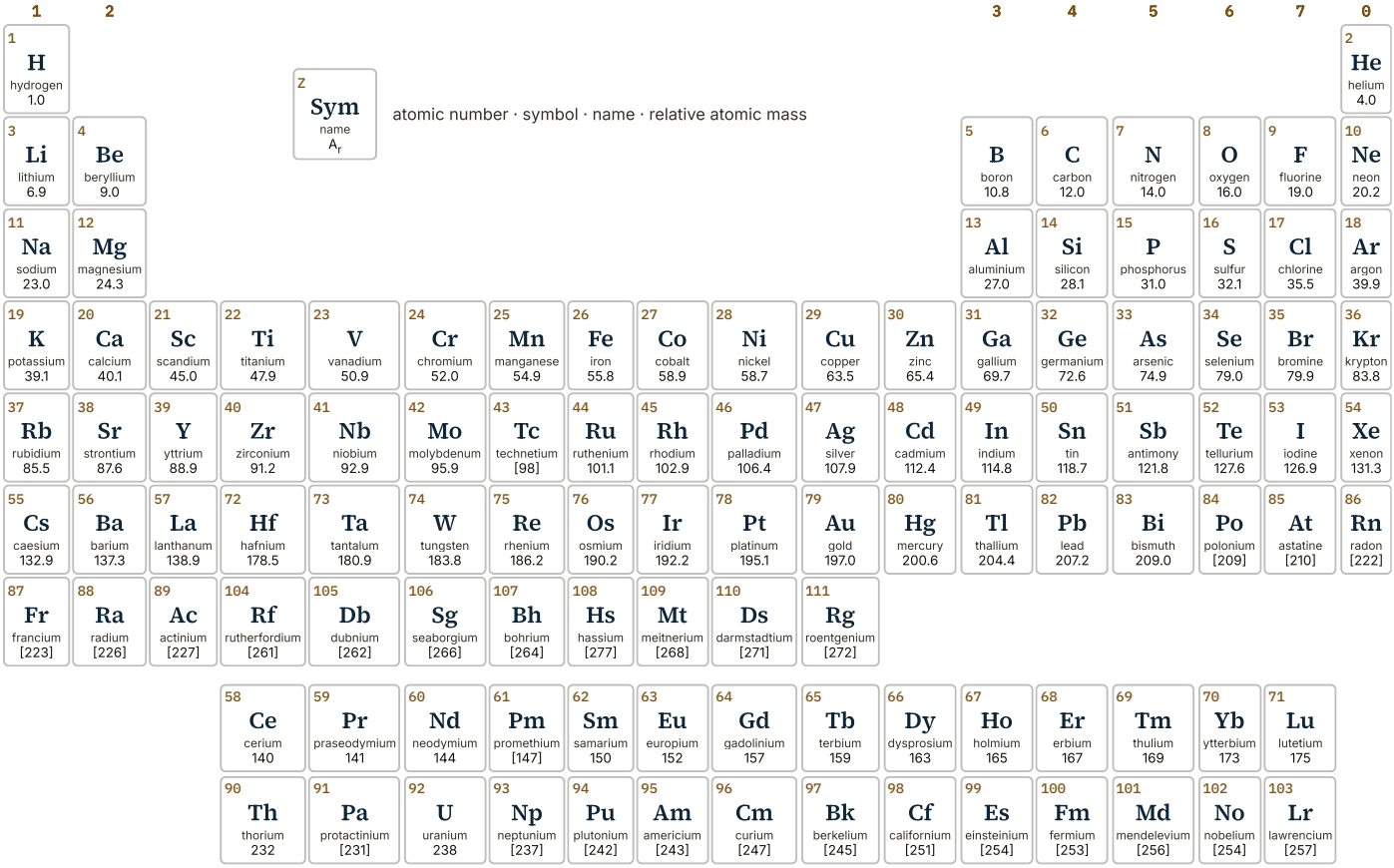
E⊖ is the standard electrode potential of the aqueous system at 298 K, that is, the standard emf of the electrochemical cell in which the hydrogen half-cell forms the left-hand side electrode system. The half-equations are the right-hand electrode systems.

No.	Right-hand electrode system	$E^\ominus$ / V
1	$\mathrm{Na^+ + e^- \rightleftharpoons Na}$	−2.71
2	$\mathrm{Mg^{2+} + 2e^- \rightleftharpoons Mg}$	−2.37
3	$\mathrm{Al^{3+} + 3e^- \rightleftharpoons Al}$	−1.66
4	$\mathrm{V^{2+} + 2e^- \rightleftharpoons V}$	−1.18
5	$\mathrm{Zn^{2+} + 2e^- \rightleftharpoons Zn}$	−0.76
6	$\mathrm{Cr^{3+} + 3e^- \rightleftharpoons Cr}$	−0.74
7	$\mathrm{Fe^{2+} + 2e^- \rightleftharpoons Fe}$	−0.44
8	$\mathrm{Cr^{3+} + e^- \rightleftharpoons Cr^{2+}}$	−0.41
9	$\mathrm{V^{3+} + e^- \rightleftharpoons V^{2+}}$	−0.26
10	$\mathrm{Ni^{2+} + 2e^- \rightleftharpoons Ni}$	−0.25
11	$\mathrm{H^+ + e^- \rightleftharpoons \tfrac{1}{2}H_2}$	0.00
12	$\mathrm{S_4O_6^{2-} + 2e^- \rightleftharpoons 2S_2O_3^{2-}}$	+0.09
13	$\mathrm{Cu^{2+} + e^- \rightleftharpoons Cu^+}$	+0.15
14	$\mathrm{Cu^{2+} + 2e^- \rightleftharpoons Cu}$	+0.34
15	$\mathrm{VO^{2+} + 2H^+ + e^- \rightleftharpoons V^{3+} + H_2O}$	+0.34
16	$\mathrm{O_2 + 2H_2O + 4e^- \rightleftharpoons 4OH^-}$	+0.40
17	$\mathrm{S_2O_3^{2-} + 6H^+ + 4e^- \rightleftharpoons 2S + 3H_2O}$	+0.47
18	$\mathrm{Cu^+ + e^- \rightleftharpoons Cu}$	+0.52
19	$\mathrm{I_2 + 2e^- \rightleftharpoons 2I^-}$	+0.54
20	$\mathrm{O_2 + 2H^+ + 2e^- \rightleftharpoons H_2O_2}$	+0.68
21	$\mathrm{Fe^{3+} + e^- \rightleftharpoons Fe^{2+}}$	+0.77
22	$\mathrm{Ag^+ + e^- \rightleftharpoons Ag}$	+0.80
23	$\mathrm{NO_3^- + 2H^+ + e^- \rightleftharpoons NO_2 + H_2O}$	+0.80
24	$\mathrm{ClO^- + H_2O + 2e^- \rightleftharpoons Cl^- + 2OH^-}$	+0.89
25	$\mathrm{VO_2^+ + 2H^+ + e^- \rightleftharpoons VO^{2+} + H_2O}$	+1.00
26	$\mathrm{Br_2 + 2e^- \rightleftharpoons 2Br^-}$	+1.09
27	$\mathrm{O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O}$	+1.23
28	$\mathrm{Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O}$	+1.33
29	$\mathrm{Cl_2 + 2e^- \rightleftharpoons 2Cl^-}$	+1.36
30	$\mathrm{MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O}$	+1.51

No.	Right-hand electrode system	$E^{\ominus}$ / V
31	$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1.77

The periodic table of elements

Groups are numbered 1 to 7 and 0 (8), with the group numbers (1) to (18) as printed. Elements with atomic numbers 112 to 116 have been reported but not fully authenticated (as printed). Masses in square brackets are as printed; lanthanide and actinide masses are whole numbers as printed.



Infrared spectroscopy: correlation of infrared absorption wavenumbers with molecular structure

Vibration	Group	Wavenumber range / cm^{-1}
C-H stretching	alkane	2962 to 2853
C-H stretching	alkene	3095 to 3010
C-H stretching	alkyne	3300
C-H stretching	arene	3030
C-H stretching	aldehyde	2900 to 2820 and 2775 to 2700
C-H bending	alkane	1485 to 1365
C-H bending	arene, 5 adjacent hydrogen atoms	750 and 700
C-H bending	arene, 4 adjacent hydrogen atoms	750
C-H bending	arene, 3 adjacent hydrogen atoms	780
C-H bending	arene, 2 adjacent hydrogen atoms	830
C-H bending	arene, 1 isolated hydrogen atom	880
N-H stretching	amine	3500 to 3300
N-H stretching	amide	3500 to 3140
O-H stretching	alcohols and phenols	3750 to 3200
O-H stretching	carboxylic acids	3300 to 2500

Vibration	Group	Wavenumber range / cm^{-1}
C=C stretching	isolated alkene	1669 to 1645
C=C stretching	arene	1600, 1580, 1500, 1450
C=O stretching	aldehydes, saturated alkyl	1740 to 1720
C=O stretching	ketones, alkyl	1720 to 1700
C=O stretching	ketones, aryl	1700 to 1680
C=O stretching	carboxylic acids, alkyl	1725 to 1700
C=O stretching	carboxylic acids, aryl	1700 to 1680
C=O stretching	carboxylic acid anhydrides	1850 to 1800 and 1790 to 1740
C=O stretching	acyl halides, chlorides	1795
C=O stretching	acyl halides, bromides	1810
C=O stretching	esters, saturated	1750 to 1735
C=O stretching	amides	1700 to 1630
Triple bond stretching	C≡N	2260 to 2215
Triple bond stretching	C≡C	2260 to 2100

1H nuclear magnetic resonance chemical shifts relative to tetramethylsilane (TMS)

The booklet prints this as a chart of boxes on a scale from 12.0 to 0.0 ppm, with no numbers on the boxes. The ranges here were measured from the box edges against the printed scale and rounded to the nearest 0.5 ppm, so treat them as approximate: the chart is a guide, and its own reference marks sit up to 0.3 ppm from the scale. The bold H in the booklet marks the proton described.

Proton	Environment as labelled	δ / ppm (about)
$\mathrm{C}\mathbf{H}$ in $\mathrm{R_3CH} > \mathrm{R_2CH_2} > \mathrm{RCH_3}$	alkane, H-C-C	0.0 to 1.5
$\mathbf{H}$-C=C	alkene	4.5 to 6.5
Ar-$\mathbf{H}$	arene ring	6.5 to 8.5
$-\mathrm{CO}$-$\mathbf{H}$	aldehyde	9.0 to 10.0
$\mathbf{H}$-C-halogen ($\mathrm{R_2CHF} > \mathrm{R_2CHCl} > \mathrm{R_2CHBr} > \mathrm{R_2CHI}$)	halogenoalkane	2.0 to 4.0
$\mathbf{H}$-C-O-	alcohol, ether, ester	3.0 to 4.0
$-\mathrm{O}$-$\mathbf{H}$	alcohol	2.0 to 4.0
COO-$\mathbf{H}$	carboxylic acid	10.0 to 12.0
Ar-O-$\mathbf{H}$	phenol	4.0 to 7.5
$\mathbf{H}$-C-C=O	aldehyde, ketone, ester, amide, acid	1.5 to 3.0
$\mathbf{H}$-C-C=C	alkenes, arenes	1.5 to 3.0
$\mathbf{H}$-C-N	amine, amide	2.5 to 3.5
Ar-N-$\mathbf{H}$	phenylamines	3.0 to 5.0
C-N-$\mathbf{H}$	amine	0.5 to 3.0
CON-$\mathbf{H}$	amide	5.0 to 9.0

Also learn these

Empirical formula from percentages

Divide each percentage by its Ar, divide all the results by the smallest, then scale to whole numbers. Used in: Oct 2023 Q19(a); Jan 2023 Q18; Oct 2019 Q24(f)(i).

Limiting reagent

Work out the moles of each reactant and compare them with the equation; the smaller amount, after allowing for the ratio, limits the yield. Used in: Jan 2026 Q18(a)(i).

Oxidation numbers

The oxidation numbers in a species add up to its charge, so find the metal by taking the others from the formula. Used in: Jan 2026 Q23(c)(ii); Oct 2019 Q1; Oct 2019 Q5.

Feasibility from Ecell

A positive Ecell means the reaction is thermodynamically feasible, but a high activation energy can still stop it, and non-standard conditions can change the answer. Used in: Jan 2026 Q22(b)(iv); Jun 2022 Q17(a)(ii); Oct 2019 Q20(d)(ii), disproportionation.

Standard conditions for electrode potentials

298 K, 100 kPa for gases and 1.00 mol dm^{-3} for ions, with a platinum electrode in contact with the hydrogen half-cell. Used in: Jan 2026 Q1; Jan 2026 (A) Q1(c); Oct 2019 Q16.

Complexes: coordination number and shape

Count the dative bonds to get the coordination number, using 2 for each bidentate ligand; four-coordinate complexes are tetrahedral or square planar, and six-coordinate are octahedral. Used in: Jan 2026 Q7; Oct 2019 Q3; Oct 2019 Q4.

Reading a calibration graph

In colorimetry read the concentration from the calibration graph at the measured absorbance, and say if the reading lies outside the range of the data. Used in: Oct 2025 Q14; Oct 2024 Q18(c).

Mass spectrum, infrared and NMR data

Use the molecular ion peak for Mr, the booklet's infrared table for bonds, and the number of carbon-13 peaks for the carbon environments. Used in: Jan 2026 Q15(a); Oct 2025 Q11; Jun 2025 Q20.

Using the booklet in the exam

- Take each standard electrode potential from the booklet as a reduction, then use Ecell = E(right) - E(left) and check the sign: a feasible reaction has a positive Ecell.
- Read the question for the equation before you try to recall it. The Nernst equation, F = 96 500 C mol^{-1} and the Oct 2025 equations for Ecell, ΔStotal and ln K were all printed.
- In a redox titration write the balanced ratio first, then scale a 25.0 cm^3 sample up to the 250.0 cm^3 flask before you find the mass or percentage.
- For a percentage uncertainty use two readings for a titre, then divide by the value measured and multiply by 100.
- For a multi-step synthesis multiply the step yields as fractions, and apply the result to the theoretical mass from the first reactant.
- Convert cm^3 to dm^3 before using c = n / V, and take 24 dm^3 mol^{-1} for a gas at r.t.p. from the booklet.

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