# Stoichiometry

IB SL Study Guide

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IB TIP

**Data booklet:** You can use the IB Chemistry Data Booklet in the exam — all constants, the periodic table, and key equations are provided.

# IB Chemistry SL — Stoichiometry & From Models to Materials

**Complete Study Guide**

**Topics Covered**

1. The Mole Concept and Molar Mass (R2.1)
2. Avogadro's Number and Counting Particles (R2.1)
3. Mole Ratios and Balanced Equations (R2.1)
4. Limiting Reagent and Excess Reagent (R2.1)
5. Theoretical Yield, Actual Yield, and Percentage Yield (R2.1)
6. Atom Economy (R2.1)
7. Allotropes of Carbon (S2.4)
8. Polymers — Addition and Condensation (S2.4)
9. Semiconductors and Superconductors (S2.4)

**Prerequisites:** The mole concept was introduced in **Atomic Structure (Structure 1.4)**. This guide extends that foundation to reactions — you will apply mole calculations to balanced equations. For the Structure 2.4 section, familiarity with covalent bonding and giant covalent structures from **Bonding & Structure (Structure 2)** is assumed.

## 1. The Mole Concept and Molar Mass (R2.1)

Stoichiometry is the quantitative study of the amounts of substances involved in chemical reactions. The **mole** is the central unit: it bridges the microscopic world of atoms and molecules with the macroscopic world of masses and volumes that we can measure in the laboratory.

### Defining the Mole

One **mole** of any substance contains exactly $6.022 \times 10^{23}$ elementary entities (atoms, molecules, ions, or formula units). This number is **Avogadro's constant** ($N_A$):

$$N_A = 6.022 \times 10^{23}\,\text{mol}^{-1}$$

The mole is defined so that one mole of carbon-12 atoms has a mass of exactly 12 g. This makes the numerical value of the molar mass equal to the relative atomic (or molecular) mass.

### Molar Mass

The **molar mass** ($M$) is the mass of one mole of a substance, expressed in $\mathrm{g\ mol^{-1}}$.

- For elements: $M$ numerically equals the relative atomic mass $A_r$ found on the periodic table.
  - $M(\mathrm{Na}) = 22.99\ \mathrm{g\ mol^{-1}}$
  - $M(\mathrm{O_2}) = 2 \times 16.00 = 32.00\ \mathrm{g\ mol^{-1}}$
- For compounds: sum the molar masses of all atoms in the formula.
  - $M(\mathrm{H_2SO_4}) = 2(1.008) + 32.07 + 4(16.00) = 98.09\ \mathrm{g\ mol^{-1}}$
  - $M(\mathrm{CaCO_3}) = 40.08 + 12.01 + 3(16.00) = 100.09\ \mathrm{g\ mol^{-1}}$

### The Mole–Mass Equation

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

Where:

- $n$ = amount of substance (mol)
- $m$ = mass (g)
- $M$ = molar mass ($\mathrm{g\ mol^{-1}}$)

Rearrangements: $m = nM$ and $M = \dfrac{m}{n}$

**MEMORISE THIS**

**Three quantities, one triangle:** Draw a triangle with $m$ on top, $n$ and $M$ on the bottom. Cover the quantity you want:

- Cover $n \rightarrow n = m \div M$
- Cover $m \rightarrow m = n \times M$
- Cover $M \rightarrow M = m \div n$

Always check units: mass in grams, molar mass in $\mathrm{g\ mol^{-1}}$, amount in mol.

## 2. Avogadro's Number and Counting Particles (R2.1)

The relationship between amount in moles and number of particles is:

$N = n \times N_A$

Where $N$ is the number of particles.

WORKED EXAMPLE

**Worked Example 1 — Mole and particle calculations**

**Part (a):** Calculate the number of molecules in 4.40 g of carbon dioxide ($CO_2$).

Step 1 — Molar mass: $M(\mathrm{CO_2}) = 12.01 + 2(16.00) = 44.01\,\mathrm{g\,mol^{-1}}$

Step 2 — Find moles: $n = \frac{4.40}{44.01} = 0.0999 \approx 0.100\,\mathrm{mol}$

Step 3 — Find number of molecules: $N = 0.100 \times 6.022 \times 10^{23} = 6.02 \times 10^{22}$ molecules

**Part (b):** What mass of sodium chloride (NaCl) contains $1.81 \times 10^{24}$ formula units?

Step 1 — Find moles: $n = \dfrac{1.81 \times 10^{24}}{6.022 \times 10^{23}} = 3.005 \approx 3.00\,\mathrm{mol}$

Step 2 — Find mass: $M(\mathrm{NaCl}) = 22.99 + 35.45 = 58.44\,\mathrm{g\,mol^{-1}}$ $m = 3.00 \times 58.44 = 175.3 \approx 175\,\mathrm{g}$

EXAM ALERT

**Exam trap — what counts as a "particle":** The question will specify whether it wants atoms, molecules, ions, or formula units. For NaCl, one mole contains $N_A$ formula units, but $2N_A$ ions (one $Na^+$ and one $Cl^-$ per formula unit). For $H_2O$, one mole contains $N_A$ molecules but $3N_A$ atoms. Always read the question carefully.

# 3. Mole Ratios and Balanced Equations (R2.1)

A **balanced chemical equation** tells you not just what reacts and what is produced, but also the exact **mole ratios** in which substances react and are produced. The stoichiometric coefficients ARE the mole ratios.

$$\mathrm{N_2}(g) + 3\mathrm{H_2}(g) \rightarrow 2\mathrm{NH_3}(g)$$

This equation means: 1 mol of $N_2$ reacts with 3 mol of $H_2$ to produce 2 mol of $NH_3$.

## Strategy for Stoichiometry Problems

1. Write (or check) the balanced equation.
2. Convert the given quantity to **moles**.
3. Use the **mole ratio** from the equation to find moles of the target substance.
4. Convert moles of the target substance to the required quantity (mass, volume, number of particles).

WORKED EXAMPLE

**Worked Example 2 — Stoichiometric mass calculation**

Magnesium burns in oxygen according to:

$2\text{Mg}(s) + \text{O}_2(g) \rightarrow 2\text{MgO}(s)$

What mass of MgO is produced when 3.60 g of Mg is completely burned?

**Step 1:** Find moles of Mg. $M(\text{Mg}) = 24.31\ \text{g mol}^{-1}$ $n(\text{Mg}) = \frac{3.60}{24.31} = 0.1481\ \text{mol}$

**Step 2:** Apply the mole ratio. From the equation, the ratio $\text{Mg} : \text{MgO} = 2 : 2 = 1 : 1$. $n(\text{MgO}) = 0.1481\ \text{mol}$

**Step 3:** Find mass of MgO. $M(\text{MgO}) = 24.31 + 16.00 = 40.31\ \text{g mol}^{-1}$ $m(\text{MgO}) = 0.1481 \times 40.31 = 5.97\ \text{g}$

EXAM ALERT

**Exam trap — unbalanced equations:** If you are given or write an unbalanced equation and use the wrong mole ratio, you will get the wrong answer even if your arithmetic is correct. Always check that the equation is balanced before extracting ratios. In an IB exam, check that atoms AND charges are balanced.

## 4. Limiting Reagent and Excess Reagent (R2.1)

In most real reactions, the reactants are not mixed in exactly the stoichiometric ratio. The **limiting reagent** (also called the limiting reactant) is the reactant that is completely used up first — it limits how much product can form. The **excess reagent** is the reactant that remains after the reaction is complete.

### Identifying the Limiting Reagent

**Method:** Convert all given masses to moles, then divide each by its stoichiometric coefficient. The reactant with the **smallest** value is the limiting reagent.

WORKED EXAMPLE

**Worked Example 3 — Finding the limiting reagent**

Iron reacts with chlorine gas:

$2\text{Fe}(s) + 3\text{Cl}_2(g) \rightarrow 2\text{FeCl}_3(s)$

15.0 g of Fe is mixed with 15.0 g of $Cl_2$. Identify the limiting reagent and calculate the mass of $FeCl_3$ produced.

**Step 1:** Convert to moles. $n(\text{Fe}) = \frac{15.0}{55.85} = 0.2686\,\text{mol}$ $n(\text{Cl}_2) = \frac{15.0}{70.90} = 0.2116\,\text{mol}$

**Step 2:** Divide by stoichiometric coefficients to compare. $\frac{n(\text{Fe})}{2} = \frac{0.2686}{2} = 0.1343$ $\frac{n(\text{Cl}_2)}{3} = \frac{0.2116}{3} = 0.0705$

The smaller value is for $Cl_2$, so $Cl_2$ **is the limiting reagent**.

**Step 3:** Calculate moles of $FeCl_3$ based on limiting reagent. Ratio $\text{Cl}_2 : \text{FeCl}_3 = 3 : 2$ $n(\text{FeCl}_3) = 0.2116 \times \frac{2}{3} = 0.1411\,\text{mol}$

**Step 4:** Find mass of $FeCl_3$. $M(\text{FeCl}_3) = 55.85 + 3(35.45) = 162.20\,\text{g mol}^{-1}$ $m(\text{FeCl}_3) = 0.1411 \times 162.20 = 22.9\,\text{g}$

IB TIP

**IB Tip:** A quick way to check which is limiting: if you used all of reactant A, how much of B would you need? If you need more B than you have, then B is limiting. This "hypothetical use" method is useful for checking your answer, but the divide-by-coefficient method above is more systematic for complex problems.

# 5. Theoretical Yield, Actual Yield, and Percentage Yield (R2.1)

## Definitions

- **Theoretical yield:** The maximum mass of product predicted by stoichiometry, assuming the limiting reagent is completely consumed and no side reactions occur. This is calculated from the balanced equation.
- **Actual yield:** The mass of product actually obtained in the laboratory. This is always less than or equal to the theoretical yield.
- **Percentage yield:** The ratio of actual to theoretical yield, expressed as a percentage.

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

### Why is the Actual Yield Always Less?

- Some product is lost during transfer, filtration, or purification.
- Side reactions produce unwanted by-products.
- The reaction may not go to completion (equilibrium is established).
- The limiting reagent may not be completely pure.

WORKED EXAMPLE

**Worked Example 4 — Percentage yield**

In the reaction: $CH_3COOH(l) + C_2H_5OH(l) \rightleftharpoons CH_3COOC_2H_5(l) + H_2O(l)$

12.0 g of ethanoic acid ($CH_3COOH$) is reacted with excess ethanol. 10.4 g of ethyl ethanoate ($CH_3COOC_2H_5$) is isolated.

Calculate the percentage yield.

**Step 1:** Find moles of $CH_3COOH$ (the limiting reagent, since ethanol is in excess).
$M(CH_3COOH) = 2(12.01) + 4(1.008) + 2(16.00) = 60.05\,\text{g mol}^{-1}$
$n(CH_3COOH) = \frac{12.0}{60.05} = 0.1998\,\text{mol}$

**Step 2:** Find theoretical yield of ester. Mole ratio $1:1$, so $n(\text{ester}) = 0.1998\,\text{mol}$.
$M(CH_3COOC_2H_5) = 4(12.01) + 8(1.008) + 2(16.00) = 88.11\,\text{g mol}^{-1}$
$\text{theoretical yield} = 0.1998 \times 88.11 = 17.60\,\text{g}$

**Step 3:** Calculate percentage yield. $\%\text{ yield} = \frac{10.4}{17.60} \times 100 = 59.1\%$

EXAM ALERT

**Exam trap — yield vs. purity:** Percentage yield measures how much of the theoretical product you obtained. It does NOT measure purity. A product with 100% yield could still be contaminated. Purity is determined separately (e.g. by titration or spectroscopy). The exam may distinguish these — do not confuse them.

# 6. Atom Economy (R2.1)

**Atom economy** is a measure of how efficiently atoms in the reactants end up in the desired product. It was introduced by Barry Trost as a principle of green chemistry — maximising atom economy minimises waste.

$$\%\text{ atom economy} = \frac{\text{molar mass of desired product(s)}}{\text{total molar mass of all products}} \times 100\%$$

Equivalently (since mass is conserved):

$$\%\text{ atom economy} = \frac{\text{molar mass of desired product(s)}}{\text{total molar mass of all reactants}} \times 100\%$$

### Why Atom Economy Matters

- High atom economy → less waste → more sustainable process → lower cost of raw materials.
- A reaction can have a high percentage yield but low atom economy if many by-products are formed.
- **Addition reactions** always have 100% atom economy (all atoms in the reactants end up in the one product).
- **Substitution reactions** typically have lower atom economy (a leaving group is produced as waste).

WORKED EXAMPLE

**Worked Example 5 — Atom economy**

Chlorine gas can be produced by two processes:

**Process 1 (addition/synthesis type):** $2\text{NaCl}(s) + 2\text{H}_2\text{O}(l) \rightarrow \text{Cl}_2(g) + \text{H}_2(g) + 2\text{NaOH}(aq)$

Here the desired product is $\text{Cl}_2$. $\text{H}_2$ and NaOH are co-products (may be sold or used).

$M(\text{Cl}_2) = 70.90\,\text{g mol}^{-1}$ Total molar mass of all products $= 70.90 + 2.016 + 2(40.00) = 152.92\,\text{g mol}^{-1}$ % atom economy $= \frac{70.90}{152.92} \times 100 = 46.4\%$

**Note:** If both $\text{Cl}_2$ and NaOH are considered desired products (both are commercially valuable), the atom economy increases substantially — context matters.

**Process 2 (substitution type, simplified):** If only $\text{Cl}_2$ is desired and all other products are waste, atom economy = 46.4% as calculated.

IB TIP

**IB Tip:** The IB exam may ask you to calculate atom economy from a given equation and then comment on sustainability. A high atom economy does not automatically mean a reaction is green — energy use, safety of reagents, and reaction conditions also matter. However, for the exam, the calculation is the key skill.

MEMORISE THIS

**Yield vs. atom economy — a comparison:**

| | % Yield | % Atom Economy |
|---|---|---|
| **What it measures** | How much of the theoretical product was actually obtained | What fraction of reactant atoms end up in the desired product |
| **Based on** | Actual experimental result vs. calculated maximum | Molar masses from the balanced equation (no experimental data needed) |
| **Can be 100%?** | Only if no product is lost | Yes — for addition reactions |
| **Relevance** | Practical efficiency of a specific experiment | Environmental/economic sustainability of a reaction |

# 7. Allotropes of Carbon (S2.4)

An **allotrope** is one of two or more physically distinct forms of the same element in the same physical state, differing in the way atoms are bonded or arranged. Carbon has four well-known allotropes you must understand for IB SL.

## Diamond

- **Structure:** Each carbon atom is bonded to **four** other carbon atoms by strong $\sigma$ (single) covalent bonds in a tetrahedral arrangement, forming a giant covalent (macromolecular) network lattice.
- **Hybridisation:** $sp^3$
- **Properties:**
  - Hardest natural substance — the rigid 3D network of covalent bonds is extremely difficult to break.
  - Does not conduct electricity — all four valence electrons are used in C-C bonds; there are no free (delocalised) electrons.
  - Very high melting point ($> 3500$°C) — enormous number of strong covalent bonds must be broken.
  - Transparent and colourless.

## Graphite

- **Structure:** Each carbon atom is bonded to **three** other carbon atoms in flat **hexagonal layers** (planar sheets). The layers are held together by weak London dispersion (van der Waals) forces.
- **Hybridisation:** $sp^2$; the remaining $p$ orbital on each carbon is perpendicular to the plane and overlaps with adjacent $p$ orbitals to form a **delocalised $\pi$ electron system** across each layer.
- **Properties:**
  - Conducts electricity — the delocalised $\pi$ electrons are free to move along the layers; graphite is unusual among non-metals in being a conductor.
  - Soft and slippery — layers can slide past each other because only weak London dispersion forces hold the layers together; used as a lubricant and in pencil “leads.”

- High melting point — strong covalent bonds within each layer require a lot of energy to break; but layers can be separated relatively easily.

⚠ EXAM ALERT

**Exam trap — why graphite conducts:** Students often say "graphite has free electrons." This is imprecise. You must specify that the **delocalised $\pi$ electrons** (from the unhybridised $p$ orbitals, one per carbon) are free to move within the layers. Conduction occurs **along** the layers, not perpendicular to them. Saying "there are mobile electrons" without explaining their source earns partial credit at best.

### Graphene

- **Structure:** A **single layer** of graphite — one atom thick, arranged in a hexagonal honeycomb lattice. Graphene can be thought of as the building block of graphite.
- **Hybridisation:** $sp^2$ (same as graphite)
- **Properties:**
  - Exceptional electrical and thermal conductor — delocalised electrons can move across the entire 2D sheet.
  - Strongest material ever tested (per unit area) — due to the extensive covalent network.
  - Transparent, flexible, and nearly massless per unit area.
  - Applications: flexible electronics, sensors, reinforcement in composites.

### Fullerenes (Buckminsterfullerene — $C_{60}$)

- **Structure:** Carbon atoms form a **closed cage** of hexagonal and pentagonal rings. $C_{60}$ (buckminsterfullerene, "buckyball") has 60 carbon atoms arranged like a soccer ball: 20 hexagons and 12 pentagons.
- **Hybridisation:** Approximately $sp^2$; the molecule is nearly spherical.
- **Properties:**
  - Molecular (not giant covalent) — discrete $C_{60}$ molecules held together by London dispersion forces in the solid.
  - Relatively low melting point (sublimes around 600°C) compared to diamond or graphite.
  - Semiconducting properties; can become superconducting when doped with alkali metals.
  - Can encapsulate other atoms or molecules inside the cage ("endohedral fullerenes") — applications in drug delivery.

MEMORISE THIS

**Carbon allotrope comparison:**

| Property | Diamond | Graphite | Graphene | $C_{60}$ |
|---|---|---|---|---|
| Structure | Giant covalent (3D) | Giant covalent (2D layers) | Single layer (2D) | Discrete molecule |
| C-C bonds per C | 4 ($sp^3$) | 3 ($sp^2$) | 3 ($sp^2$) | ~3 ($sp^2$) |
| Electrical conduction | No | Yes (along layers) | Yes (excellent) | Semiconductor |
| Hardness | Hardest solid | Soft/slippery | Very strong per area | Soft solid |
| Melting point | Very high | Very high | Very high (if covalent) | Low (sublimes ~600°C) |

## 8. Polymers — Addition and Condensation (S2.4)

**Polymers** are giant molecules formed by linking many small repeating units called **monomers** together. There are two main types of polymerisation reaction at IB SL.

### Addition Polymerisation

In **addition polymerisation**, unsaturated monomers (containing C=C double bonds) join together without losing any atoms. All atoms from the monomers end up in the polymer — atom economy is 100%.

**General mechanism:** The C=C double bond in each monomer opens up; each monomer unit joins to the next.

**Example — poly(ethene) from ethene:**

$n\,CH_2{=}CH_2 \rightarrow$ -(-$CH_2$-$CH_2$-$)_n$-

**Example — poly(chloroethene) (PVC) from chloroethene:**

$n\,CH_2{=}CHCl \rightarrow$ -(-$CH_2$-CHCl-$)_n$-

> **IB TIP**
>
> **IB Tip:** To draw the repeat unit of an addition polymer from the monomer, simply replace the C=C double bond with a C-C single bond and add bonds to the left and right to show continuation of the chain. The repeat unit is shown inside brackets with a subscript $n$.

### Condensation Polymerisation

In **condensation polymerisation**, monomers join together with the simultaneous loss of a small molecule — usually water ($H_2O$) or hydrogen chloride (HCl). This means atom economy is less than 100%.

**Two categories:**

**Polyesters** — formed from a diol (two -OH groups) and a dicarboxylic acid (two -COOH groups). An ester linkage (-COO-) forms each time, with loss of water.

Example — making Terylene (PET, polyethylene terephthalate) from ethane-1,2-diol and benzene-1,4-dicarboxylic acid:

$HOCH_2CH_2OH + HOOC\text{-}C_6H_4\text{-}COOH \rightarrow \text{-}O\text{-}CH_2CH_2\text{-}OOC\text{-}C_6H_4\text{-}CO\text{-} + n\,H_2O$

**Polyamides** — formed from a diamine (two $-NH_2$ groups) and a dicarboxylic acid (two -COOH groups). An amide linkage (-CO-NH-) forms, with loss of water.

Example — Nylon-6,6 from 1,6-diaminohexane and hexanedioic acid:

$H_2N\text{-}(CH_2)_6\text{-}NH_2 + HOOC\text{-}(CH_2)_4\text{-}COOH \rightarrow$
$\text{-}NH\text{-}(CH_2)_6\text{-}NH\text{-}CO\text{-}(CH_2)_4\text{-}CO\text{-} + n\,H_2O$

⚠ EXAM ALERT

**Exam trap — identifying polymer type from structure:** If the backbone of the polymer contains only C-C single bonds (with pendant groups), it is an addition polymer. If the backbone contains ester linkages (-COO-) or amide linkages (-CO-NH-), it is a condensation polymer. You may also be asked to identify the monomer(s) from the repeat unit — for condensation polymers, split at the linkage and add back the $H_2O$ that was lost.

### Environmental Considerations

- Many addition polymers (e.g. polyethene, PVC) are non-biodegradable — they persist in the environment for centuries.
- Condensation polymers (e.g. polyesters, polyamides) can sometimes be hydrolysed — broken down by water (and acid or base) — making some more degradable.
- Biodegradable polymers (e.g. polylactic acid, PLA) are increasingly being developed; they contain ester linkages that hydrolyse in the environment.

## 9. Semiconductors and Superconductors (S2.4)

### Semiconductors

**Metals** conduct electricity because their valence electrons are delocalised and free to move. **Insulators** (like diamond) have all electrons in bonding orbitals with no free electrons and a large energy gap to the conduction band.

**Semiconductors** have an intermediate situation: at low temperatures they behave as insulators, but at higher temperatures (or when doped), electrons gain enough energy to move into the conduction band.

The two most important semiconductors are silicon (Si) and germanium (Ge), both in Group 14. Like diamond, they have giant covalent structures with each atom bonded to four others — but the energy gap to the conduction band is smaller.

**Doping** — adding tiny amounts of impurity elements — dramatically changes the electrical properties:

| Dopant type | Element added | Effect |
|---|---|---|
| **n-type** | Group 15 element (e.g. P, As) — 5 valence electrons | Extra electron (negative charge carrier) per dopant atom |
| **p-type** | Group 13 element (e.g. B, Al) — 3 valence electrons | Creates a "hole" (positive charge carrier) per dopant atom |

The junction between n-type and p-type semiconductors forms a **p-n junction diode**, which is the basis of transistors, LEDs, and solar cells.

IB TIP

**IB Tip:** At SL, you do not need to describe band theory in detail. Focus on: (1) what a semiconductor is (intermediate conductivity, increases with temperature), (2) the concept of doping with Group 13 or Group 15 elements and what it achieves, and (3) one or two applications (solar cells, LEDs, transistors).

## Superconductors

A **superconductor** is a material that conducts electricity with **zero resistance** below a critical temperature ($T_c$, the critical temperature). Below $T_c$, electrical current can flow indefinitely without any energy loss.

**Key properties of superconductors:**

- Zero electrical resistance below $T_c$.
- The **Meissner effect** — a superconductor expels magnetic fields from its interior below $T_c$ (perfect diamagnetism). This enables magnetic levitation (maglev trains).
- Classical superconductors: metals like Hg, Pb, Nb at temperatures close to absolute zero (typically below 20 K).
- **High-temperature superconductors** (HTS): certain metal oxide ceramics (e.g. yttrium barium copper oxide, YBCO) become superconducting at higher temperatures — some above 130 K (−143°C), though still very cold by everyday standards.

**Applications:**

- MRI machines (magnetic resonance imaging) — superconducting magnets create intense, stable magnetic fields.
- Maglev trains — magnetic levitation using superconducting magnets eliminates friction.

- Particle accelerators (e.g. the LHC at CERN) — superconducting electromagnets steer particle beams.
- Power transmission — loss-free electrical cables (under development).

⚠ EXAM ALERT

**Exam trap — semiconductor vs. superconductor:** These are distinct phenomena. A semiconductor has reduced (but not zero) resistance that decreases as temperature increases. A superconductor has exactly zero resistance below its critical temperature. Do not say a superconductor is "a very good conductor" — the zero-resistance state is qualitatively different from conventional conduction.

MEMORISE THIS

**Super vs. Semi — a quick comparison:**

| | Semiconductor | Superconductor |
|---|---|---|
| Resistance | Decreases as temperature increases | Exactly zero below $T_c$ |
| Examples | Si, Ge | Hg (4 K), YBCO (93 K) |
| Applications | Transistors, LEDs, solar cells | MRI, maglev, particle accelerators |
| How it works | Small band gap; electrons promoted to conduction band | Cooper pairs of electrons with no scattering (quantum effect) |

## Practice Questions

Test your understanding with these IB-style questions.

### Question 1

In the reaction $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$, 4.20 g of $N_2$ is reacted with excess $H_2$. What mass of $NH_3$ is produced? ($M(\text{N}) = 14.01, M(\text{H}) = 1.008$)

A. 5.10 g

B. 8.50 g

C. 2.55 g

D. 17.0 g

### Question 2

Which allotrope of carbon is a **discrete molecule** (rather than a giant covalent structure)?

A. Diamond

B. Graphite

C. Graphene

D. $C_{60}$ (buckminsterfullerene)

**Question 3**

A reaction produces 8.20 g of product. The theoretical yield, calculated from stoichiometry, is 12.50 g. What is the percentage yield?

A. 34.1%

B. 52.4%

C. 65.6%

D. 84.0%

**Question 4**

Which of the following is the best description of a superconductor?

A. A material with very low electrical resistance at all temperatures.

B. A material with zero electrical resistance below a critical temperature.

C. A semiconductor that has been doped with a Group 15 element.

D. A polymer that can conduct electricity along its backbone.

**Question 5**

Poly(lactic acid) (PLA) is a biodegradable polymer formed from lactic acid monomers ($CH_3CH(OH)COOH$) with loss of water. What type of polymer is PLA?

A. Addition polymer

B. Condensation polymer — polyamide

C. Condensation polymer — polyester

D. Addition polymer formed from an alkene monomer

▶ Show Answers

# Next Topics

- **Classification of Matter (Structure 3)** — periodic trends and functional group classification complement the material coverage here.
- **Rates & Equilibrium (Reactivity 2.2–2.3)** — once you can calculate moles and yields, the next step is understanding what controls how fast a reaction

proceeds and what determines its equilibrium position.