

IB DIPLOMA PROGRAMME · CHEMISTRY (2023 SYLLABUS)

Structure 1.2.1

The Atomic Model

Complete revision notes, solved examples, exam-style practice questions & full mark-scheme guidance

Coverage: Structure 1.2.1 only (SL + HL). **There is no HL-only content in this syllabus point.** The HL-only mass-spectrometry content begins later at Structure 1.2.3.

0 How to use these notes

SL + HL

This booklet stays tightly within the current IB Chemistry scope for Structure 1.2.1. It develops the atomic model, the three subatomic particles, nuclear notation, and the counting of protons, neutrons and electrons in neutral atoms and ions. The atom and ion figures are **schematic**; they are designed to make particle counts and charge clear, not to teach electron configurations (that comes in Structure 1.3).

IB syllabus focus	Level	What you must be able to do	Where here
Atomic model	SL + HL	Describe an atom as a small, dense, positive nucleus containing protons and neutrons, with electrons occupying the surrounding space.	1-2
Nuclear symbol	SL + HL	Use A/Z nuclear notation to deduce the numbers of protons, neutrons and electrons in atoms and ions.	3-5
Subatomic particles	SL + HL	Know relative charge and relative mass of proton, neutron and electron; treat electron mass as negligible.	6-8
Exam application	SL + HL	Move fluently between a particle-count description and the correct atom/ion symbol.	5-9

IB SCOPE NOTE

The current guide places Structure 1.2.1 in the material studied by both SL and HL students. The additional HL content in Structure 1.2 is mass spectra (1.2.3), not the atomic-model ideas in this booklet.

1 The nuclear atom

SL + HL

Core picture: an atom has a very small, dense, positively charged nucleus. The nucleus contains **protons** and **neutrons**, collectively called **nucleons**. **Electrons** are negatively charged and occupy the space outside the nucleus.

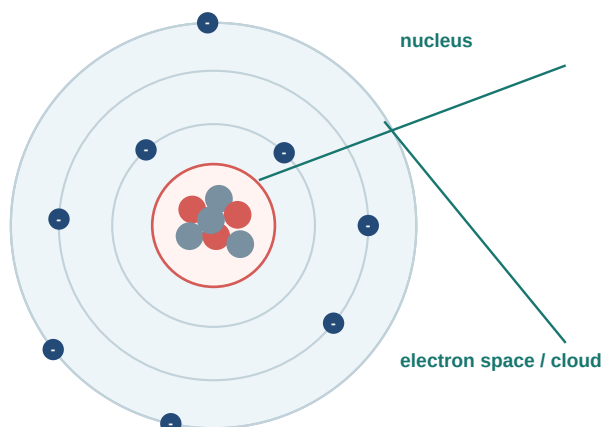
The nucleus contains virtually all of the atom's mass because protons and neutrons each have relative mass about 1, whereas the mass of an electron is tiny by comparison. The overall atom is neutral only when the number of electrons equals the number of protons.

KEY LANGUAGE TO USE IN ANSWERS

Use the words **dense nucleus**, **protons and neutrons (nucleons)**, and **electrons outside the nucleus**. Avoid saying that electrons are inside the nucleus or that neutrons contribute to electrical charge.

2 Subatomic particles and what each one does

SL + HL



THE NUCLEAR ATOM

- **Nucleus**
small, dense and positively charged
- **Proton, p⁺**
in nucleus; relative charge +1; mass ~1
- **Neutron, n⁰**
in nucleus; charge 0; mass ~1
- **Electron, e⁻**
outside nucleus; charge -1; mass negligible

Schematic only: not to scale. The nucleus is vastly smaller than the overall atom.

Particle	Symbol	Location	Relative charge	Relative mass	Exam role
Proton	p ⁺	Nucleus	+1	1	Determines atomic number / element identity
Neutron	n ⁰	Nucleus	0	1	Adds to mass number; does not affect charge
Electron	e ⁻	Outside nucleus	-1	~1/1836 (negligible)	Changes when ions form; controls net charge

DATA BOOKLET DISTINCTION

The IB data booklet provides actual particle masses and charges. For Structure 1.2.1, you still need to know the **relative** values: proton +1 / mass 1, neutron 0 / mass 1, electron -1 / negligible mass.

Nucleon is the collective word for a proton or neutron. Therefore, the total number of nucleons in a nucleus is the **mass number, A**. Electrons are not nucleons.

CLASSIC EXAM ERROR

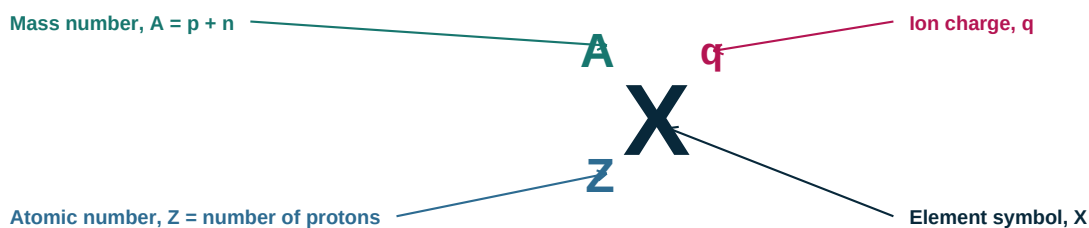
Do not calculate mass number by adding electrons. **A = protons + neutrons only**. Electron mass is neglected in this model.

Neutrality check: if p = e, positive and negative charge cancel exactly. If p > e, the species is positive. If e > p, it is negative.

3 Nuclear notation: read the symbol before doing any arithmetic

SL + HL

IB questions commonly encode the entire particle count in a nuclear symbol. Learn what each position means and use one fixed routine every time.



For a neutral atom: electrons = Z . For an ion: charge comes only from the proton-electron imbalance.

The two numbers never mean the same thing:

Quantity	Meaning	Immediate deduction
Atomic number, Z	Number of protons in the nucleus	$p = Z$
Mass number, A	Total number of nucleons (protons + neutrons)	$n = A - Z$
Ion charge, q	Overall charge produced by an imbalance of p and e	$q = p - e$

THREE-STEP ROUTINE

1. Protons = Z . 2. Neutrons = $A - Z$. 3. Electrons: neutral atom $\rightarrow e = Z$; positive ion $\rightarrow$ subtract the positive charge; negative ion $\rightarrow$ add the magnitude of the negative charge.

WORKED EXAMPLE 1 - A NEUTRAL ATOM

Q. Deduce the numbers of protons, neutrons and electrons in ${}^{23}_{11}\text{Na}$. [3]

SOLUTION

$Z = 11$, so **protons = 11**. Neutrons = $A - Z = 23 - 11 = 12$. No charge is shown, so the atom is neutral and **electrons = 11**.

WORKED EXAMPLE 2 - A POSITIVE ION

Q. Deduce p , n and e in ${}^{27}_{13}\text{Al}^{3+}$. [3]

SOLUTION

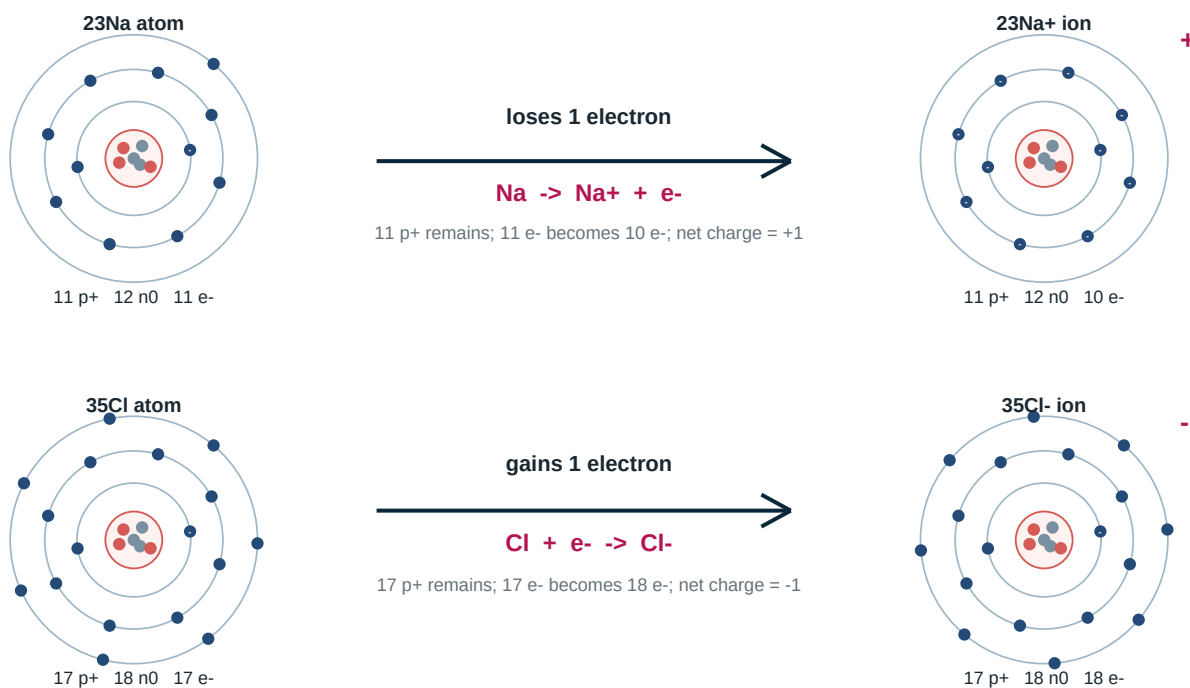
$p = 13$. $n = 27 - 13 = 14$. A $3+$ ion has three fewer electrons than protons, so $e = 13 - 3 = 10$.

4 Ions: same nucleus, different electron count

SL + HL

An **ion** is a charged species formed when the number of electrons no longer equals the number of protons. In ordinary chemical ion formation, the **nucleus is unchanged**: the element still has the same Z and the same numbers of protons and neutrons. Only the electron count changes.

FIGURE 3 - ION FORMATION: THE NUCLEUS STAYS THE SAME; THE ELECTRON COUNT CHANGES



Species type	Particle relationship	How it forms	Quick electron rule
Neutral atom	$p = e$	No net gain/loss	$e = Z$
Cation (+)	$p > e$	Loses electron(s)	$e = Z - \text{positive charge}$
Anion (-)	$e > p$	Gains electron(s)	$e = Z + \text{magnitude of negative charge}$

SIGN CHECK

A positive charge does **not** mean the ion gained protons. It means there are fewer electrons than protons. A negative charge means extra electrons are present.

The shell positions in the diagrams are only a visual way to count electrons. Detailed shell/sublevel/orbital arrangements are assessed in Structure 1.3, not here.

5 Solved examples: apply the method both ways

SL + HL

WORKED EXAMPLE 3 - AN ANION

Q. Deduce p, n and e in $^{32}_{16}\text{S}^{2-}$. [3]

SOLUTION

p = 16. n = 32 - 16 = 16. A 2- ion has two extra electrons: e = 16 + 2 = **18**.

WORKED EXAMPLE 4 - A 2+ CATION

Q. Deduce p, n and e in $^{40}_{20}\text{Ca}^{2+}$. [3]

SOLUTION

p = 20. n = 40 - 20 = 20. e = 20 - 2 = **18**.

WORKED EXAMPLE 5 - REVERSE DEDUCTION

Q. A species contains 12 protons, 13 neutrons and 10 electrons. Write its full nuclear symbol. [4]

SOLUTION

Z = 12 → the element is Mg. A = 12 + 13 = 25. There are two fewer electrons than protons, so charge = 2+. Symbol: $^{25}_{12}\text{Mg}^{2+}$.

WORKED EXAMPLE 6 - FIND THE CHARGE

Q. A species has nuclear symbol $^{56}_{26}\text{Fe}$ and contains 23 electrons. Deduce its charge. [2]

SOLUTION

Z = 26 → 26 protons. It has 23 electrons, three fewer than protons, so the net charge is **3+**.

WORKED EXAMPLE 7 - FIND THE MASS NUMBER

Q. A neutral atom contains 15 protons and 16 neutrons. Deduce A, Z and the number of electrons. [3]

SOLUTION

Z = protons = **15**. A = p + n = 15 + 16 = **31**. Neutral atom → electrons = **15**.

FAST CONSISTENCY CHECK

For any ordinary atom or ion, **p + n must equal A**. The charge must equal **p - e**. These two checks catch most arithmetic/sign errors in seconds.

6 Exam technique and common traps

SL + HL

Trap	Wrong idea	Correct correction
Confusing A and Z	"A is the atomic number."	Z is atomic number = protons. A is mass number = p + n.
Using electrons in A	"A = p + n + e."	Electrons are not nucleons; A = p + n only.
Positive ion arithmetic	For Al ³⁺ , adding 3 electrons	3+ means 3 electrons have been lost: e = Z - 3.
Negative ion arithmetic	For O ²⁻ , subtracting 2 electrons	2- means 2 electrons have been gained: e = Z + 2.
Changing the nucleus during ion formation	Changing proton or neutron count	Chemical ion formation changes electrons, not the nucleus.
Calling neutrons "neutral electrons"	Mixing particle names	Neutrons are nucleons in the nucleus; electrons are separate particles outside it.

ONE-LINE DEFINITIONS

Atomic number (Z): number of protons in the nucleus. **Mass number (A):** total number of protons and neutrons. **Ion:** a charged species in which proton and electron numbers are unequal. **Nucleon:** a proton or neutron.

EXAM METHOD CARD

Question gives...	First write...	Then calculate...
A nuclear symbol	p = Z	n = A - Z; e from the charge
p, n and e counts	Z = p	A = p + n; charge = p - e; identify element from Z
An ion name/symbol	protons from Z	Use sign of charge to gain/loss electrons

7 One-page summary

SL + HL

If the question says...	Your answer must contain...
"Describe the atomic model"	Dense positive nucleus; protons + neutrons in nucleus; electrons outside nucleus.
"Deduce protons"	p = Z.
"Deduce neutrons"	n = A - Z.
"Deduce electrons in a neutral atom"	e = Z.
"Deduce electrons in an ion"	Cation: subtract positive charge. Anion: add magnitude of negative charge.
"Write the nuclear symbol"	Find Z from p, A from p + n, element from Z, and charge from p - e.

8 Practice questions

SL + HL

Attempt these without looking back. Suggested pace: about 1-1.5 minutes per mark. Full mark-scheme guidance begins in Section 9.

Part A - Multiple choice SL + HL

1. Which particle has relative charge -1 and negligible relative mass?
A. proton B. neutron C. electron D. nucleon
2. Which statement is correct?
A. The nucleus contains electrons and neutrons. B. Protons and neutrons are nucleons. C. Electrons determine mass number. D. Neutrons have charge -1.
3. An atom has $Z = 14$ and $A = 29$. How many neutrons does it contain?
A. 14 B. 15 C. 29 D. 43
4. How many electrons are present in $^{24}_{12}\text{Mg}^{2+}$?
A. 10 B. 12 C. 14 D. 22
5. A species contains 9 protons and 10 electrons. Its charge is:
A. 1+ B. 1- C. 9+ D. neutral
6. Which quantity is unchanged when a neutral atom forms an ordinary ion?
A. electron number B. net charge C. proton number D. proton-electron difference

Part B - Structured questions SL + HL

7. State the relative charge and relative mass of a proton, neutron and electron. [3]
8. Describe the structure of an atom in terms of the nucleus and electrons. [3]
9. For $^{39}_{19}\text{K}$, deduce the numbers of protons, neutrons and electrons. [3]
10. For $^{19}_9\text{F}^-$, deduce the numbers of protons, neutrons and electrons. [3]
11. For $^{56}_{26}\text{Fe}^{3+}$, deduce p, n and e. [3]
12. A species contains 8 protons, 8 neutrons and 10 electrons. Deduce its full nuclear symbol. [4]

8 Practice questions - continued

SL + HL

Part C - Mixed exam-style questions SL + HL

13. A particle has 20 protons, 22 neutrons and 18 electrons.

- (a) State its atomic number. [1]
(b) State its mass number. [1]
(c) Deduce its charge. [1]
(d) Write its full nuclear symbol. [1]

14. Explain why the mass of an atom can be treated as concentrated in its nucleus in this model. [2]

15. The nuclear symbol of a species is ${}^{31}_{15}\text{P}^{3-}$.

- (a) State the number of nucleons. [1]
(b) Deduce the number of neutrons. [1]
(c) Deduce the number of electrons. [1]
(d) Explain why the species is negatively charged. [1]

16. A student says: "When sodium forms Na^+ , it gains a proton, so its positive charge increases." Identify two errors in this statement and give the correct explanation. [3]

17. Species X contains 17 protons and 18 electrons. Species Y contains 17 protons and 17 electrons.

- (a) Which species is neutral? [1]
(b) Deduce the charge on the other species. [1]
(c) Explain why X and Y are the same element. [1]

18. Complete the table. [8]

${}^{27}_{13}\text{Al}^{3+}$	13	—	—	3+
${}^{16}_8\text{O}^{2-}$	—	8	—	—
${}^{40}_{20}\text{Ca}$	—	—	—	0
unknown species	12	12	10	—

BEFORE CHECKING THE ANSWERS

For every line, verify two identities: $A = p + n$ and $\text{charge} = p - e$. If either fails, revisit the sign or subtraction.

19. A student is given the species ${}^{35}_{17}\text{Cl}^-$ and writes: $p = 17$, $n = 18$, $e = 16$. Identify the incorrect value, give the correct value, and explain the sign error. [3]

20. Write one concise sentence defining each term: (a) atomic number, (b) mass number, (c) nucleon, (d) ion. [4]

9 Answers & mark-scheme notes

SL + HL

Part A

1. **C** - electron: charge -1, relative mass negligible.
2. **B** - protons and neutrons are the two nucleons.
3. **B** - $n = A - Z = 29 - 14 = 15$.
4. **A** - Mg has $Z = 12$; Mg^{2+} has lost two electrons, so $e = 10$.
5. **B** - $p - e = 9 - 10 = -1$, so charge = 1-.
6. **C** - ion formation changes electron number, not the proton number / element identity.

Part B

7. **[3]** Proton: +1, mass 1. [1] Neutron: 0, mass 1. [1] Electron: -1, negligible mass (accept about 1/1836). [1]
8. **[3]** Small/dense positively charged nucleus. [1] Nucleus contains protons and neutrons/nucleons. [1] Negatively charged electrons occupy the space outside the nucleus. [1]
9. **[3]** $p = 19$ [1]; $n = 39 - 19 = 20$ [1]; neutral $\rightarrow e = 19$ [1].
10. **[3]** $p = 9$ [1]; $n = 19 - 9 = 10$ [1]; F^- has one extra electron $\rightarrow e = 10$ [1].
11. **[3]** $p = 26$ [1]; $n = 56 - 26 = 30$ [1]; Fe^{3+} $\rightarrow e = 23$ [1].
12. **[4]** $Z = 8$ [1]; $A = 8 + 8 = 16$ [1]; element O from $Z = 8$ [1]; 10 e vs 8 p $\rightarrow 2^-$ [1]. Symbol: $^{16}_8\text{O}^{2-}$.

MARKER LANGUAGE

Where the question asks you to **describe** the atom, naming the three particles alone is not enough. Include where they are: proton/neutron in the nucleus; electrons outside. Where the question asks you to **deduce** counts, show $A - Z$ for neutrons and make the ion-charge step explicit.

Part C - Questions 13-16

13. **[4]** (a) $Z = 20$. [1] (b) $A = 20 + 22 = 42$. [1] (c) 20 p and 18 e $\rightarrow 2^+$. [1] (d) $^{42}_{20}\text{Ca}^{2+}$. [1]
14. **[2]** Protons and neutrons each have relative mass about 1 and are located in the nucleus. [1] Electron mass is negligible, so virtually all atomic mass is in the nucleus. [1]
15. **[4]** (a) 31 nucleons. [1] (b) $n = 31 - 15 = 16$. [1] (c) $e = 15 + 3 = 18$. [1] (d) It has three more electrons than protons / electron charge exceeds proton charge by 3. [1]
16. **[3]** Error 1: Na^+ does not gain a proton; its proton number stays unchanged. [1] Error 2: the positive charge is formed by **loss of one electron**. [1] Correct explanation: after electron loss, p exceeds e by one, giving charge +1. [1]

9 Answers & mark-scheme notes - continued

SL + HL

Part C - Questions 17-20

17. [3] (a) Y is neutral because $p = e = 17$. [1] (b) X has charge 1- because it has one more electron than proton. [1] (c) Both have 17 protons / $Z = 17$, and proton number defines the element. [1]
18. [8] Al^{3+} : $n = 14$, $e = 10$. O^{2-} : $p = 8$, $e = 10$, charge = 2-. Ca: $p = 20$, $n = 20$, $e = 20$. Unknown species: charge = 2+ (12 p, 10 e). Award one mark per correct blank.
19. [3] The incorrect value is $e = 16$. [1] Correct $e = 18$. [1] A negative ion has **gained** electron(s), so Cl^- has one more electron than its 17 protons, not one fewer. [1]
20. [4] (a) Atomic number: number of protons in the nucleus. [1] (b) Mass number: total number of protons and neutrons/nucleons. [1] (c) Nucleon: a proton or neutron. [1] (d) Ion: a charged species in which the numbers of protons and electrons are unequal (or a species formed by gain/loss of electrons). [1]

10 Final checklist before the exam

SL + HL

I can...	Check
state the location, relative charge and relative mass of p^+ , n^0 and e^-	[]
explain that protons and neutrons are nucleons in a dense positive nucleus	[]
read A and Z correctly from a nuclear symbol	[]
calculate $p = Z$ and $n = A - Z$ without mixing them up	[]
calculate electron numbers for neutral atoms, cations and anions	[]
work backwards from p, n and e to A, Z, element identity and charge	[]
use charge = $p - e$ as a final check	[]

WHAT COMES NEXT

Structure 1.2.2 develops **isotopes** and relative atomic mass from isotopic abundance. Structure 1.2.3 is **HL only** and uses mass spectra. Structure 1.3 then develops electron configurations and energy levels.

Syllabus source: International Baccalaureate, *Chemistry guide*, first teaching 2023 / first assessment 2025. Content in this booklet is a teaching summary aligned to Structure 1.2.1.

End of Structure 1.2.1 - The Atomic Model