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VCE Chemistry ½
Metals & Covalent Lattices [1.3]
Workbook

Outline:

Learning Objectives:

- ☐ **CH34 [1.3.1]** - Explain the metallic bonding model.
- ☐ **CH34 [1.3.2]** - Identify properties of metals (high MP/BP, electrical & thermal conductivity, malleability & ductility, lustre).
- ☐ **CH34 [1.3.3]** - Explain the covalent lattice structures bonding & properties of diamond and graphite.

Section A: Metallic Bonding

Sub-Section: Introduction to Metals

Discussion: What are some common metals we see in real life?

Iron (Fe) → Gym weight

Gold (Au) → Necklaces

Discussion: What are some properties metals have?

Shiny → lustrous

Solid

malleable

conductive → heat

→ electricity

What types of metals exist?

Exploration: Metals on the Periodic Table

- Where are metals on the periodic table? (Label Below)
- What do we call metals found in the d-block? (Label Below) → transition
- What are Group 1 metals called? (Label Below) → alkali metal
- What are Group 2 metals called? (Label Below) → alkaline earth metal

Group

Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H 1																	He 2
2	Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
3	Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
4	K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
5	Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
6	Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
7	Fr 87	Ra 88	Ac 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110	Rg 111	Cn 112	Nh 113	Fl 114	Mc 115	Lv 116	Ts 117	Og 118

Ce 58	Pr 57	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103

Non - metals (yellow): H, He, C, N, O, F, Ne, P, S, Cl, Ar, Se, Br, Kr, I, Xe, Rn

Metalloids (green): B, Si, As, Te, At

- 80% of elements on the periodic table are metals!

Sub-Section: Metallic Bonding Structure

Let's have a look at the structure of metals!

Discussion: What does the structure of metallic bonding look like?

Active Recall: How many electrons do atoms want in their valence shells?

8 → HVIR (2)

Exploration: Metal Ion Forms

- How many electrons does each of them have? (Label Below)
- What are their shell model electron configurations? (Label Below)

Na
2,8,1

Ca
2,8,8,2

- The Sodium atom can either lose 1 electron(s) or gain 7 electron(s), and [losing] / [gaining] electrons is more likely.
- The Calcium atom can either lose 2 electron(s) or gain 6 electron(s) and [losing] / [gaining] electrons is more likely.

- The following ions will form:

Na^{+} Ca^{2+}

- Sodium has now **[lost]** / **[gained]** an electron to become a +1 charge.
- Calcium has now **[lost]** / **[gained]** an electron to become a +2 charge.
- Metals are found in ionic forms rather than being found in the regular, neutral form.

Definition

Metal Ion Forms

- Metals are found in ionic forms rather than the atomic form due to the Octet Rule being satisfied.

Question 1

Write each of the following metals in their metal ion form:

a. Lithium (Li)

Li^{+}

b. Magnesium (Mg)

Mg^{2+}

c. Aluminum (Al)

Al^{3+}

d. Zinc (Zn)

Zn^{2+}

e. Iron (Fe)

Fe^{2+} / Fe^{3+}

Extension: **Transition Metals**

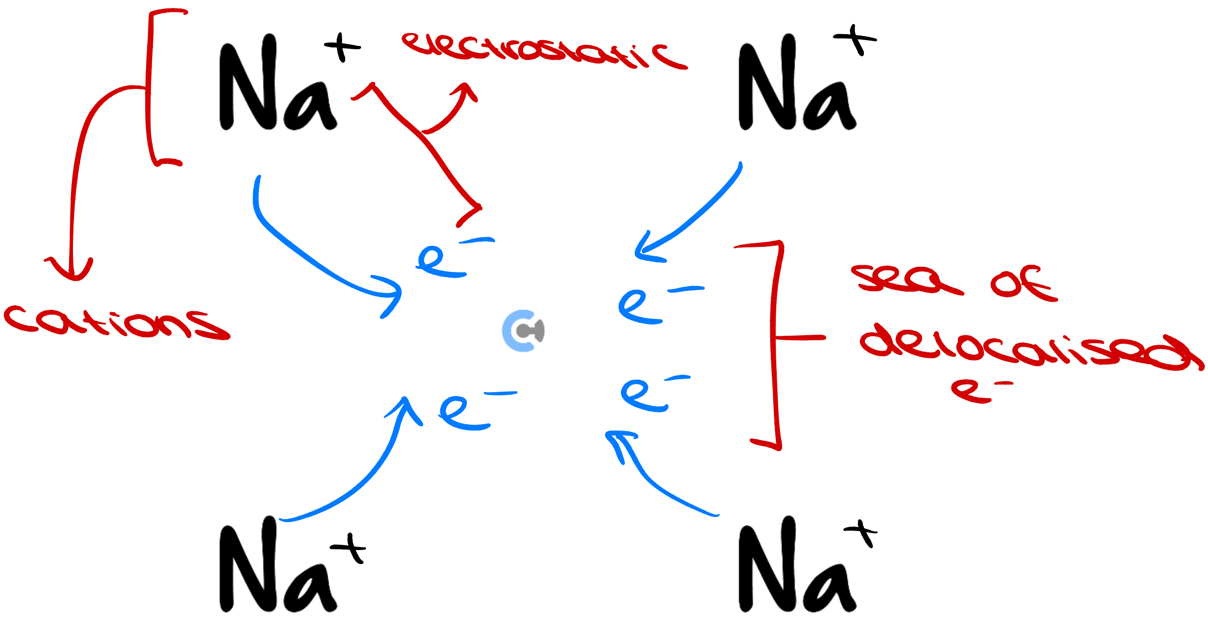
- Transition metals can form different ions due to their d-orbital electrons leading to coordination complexes being formed (University Chemistry, so don't worry).

NOTE: Transition metals typically form cations with a $+2$ charge due to the two s-orbital electrons and other charges as well.

Let's have a look at what metal ionisation looks like!

Exploration: Metallic Bonding

- Consider adjacent Sodium atoms **prior to ionisation:**

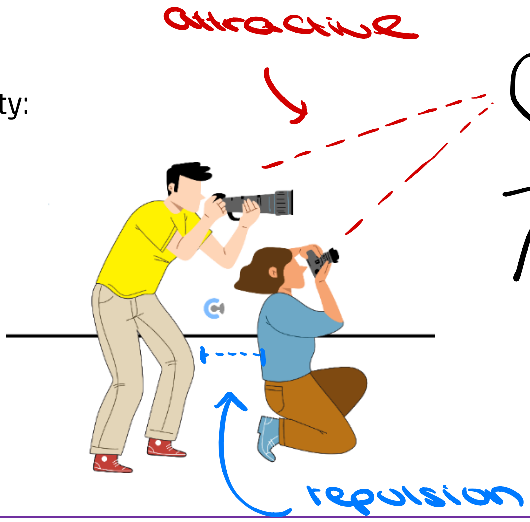


- The metals ionise, shooting electrons out. (Label Above)
- Creates a 'sea of delocalised electrons'.
- What charges do the metal cations and the delocalised electrons have? (Label Above)
- This causes electrostatic __forces__ between them. (Label Above)

Discussion: Why does the structure still hold despite the cations repelling one another?

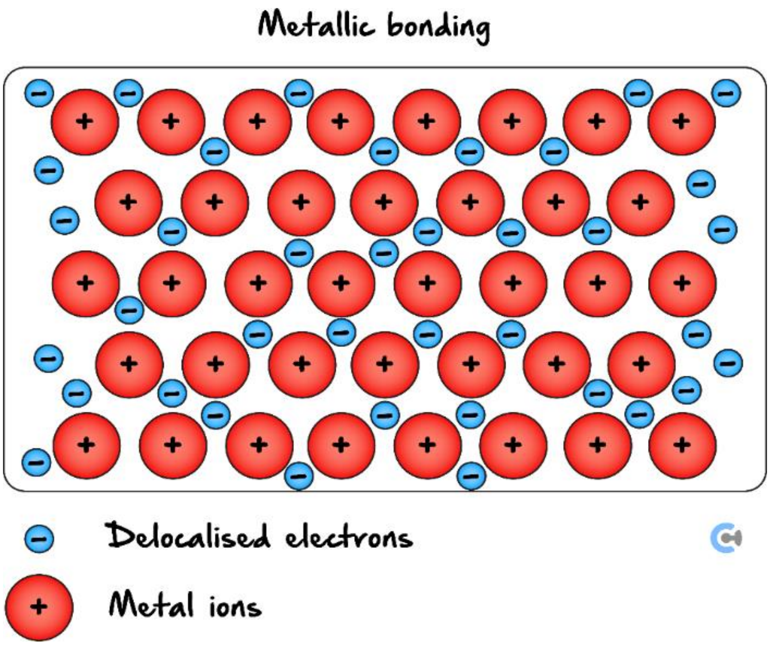
Analogy: Paparazzi

- Imagine paparazzi and a celebrity:



Metallic Bonding Structure

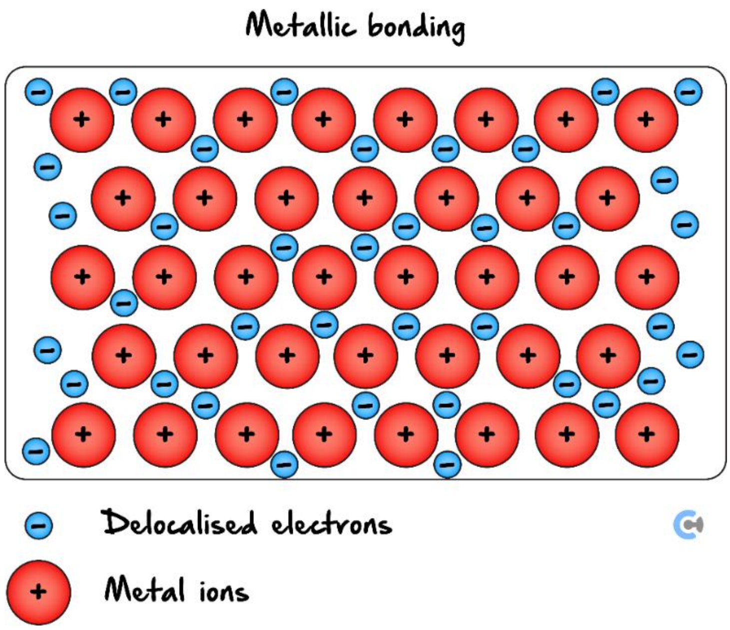
- The metal cations are in a tightly packed regular arrangement, known as a lattice.



Definition

Metallic Bonding

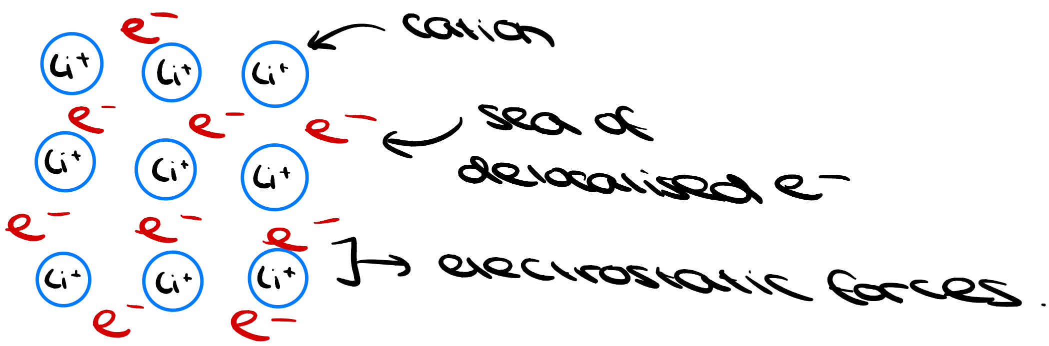
- Metallic bonding is caused by electrostatic attraction between metal cations and electrons which have been lost.
- The lost electrons group together in a **'sea of delocalised electrons'**.
- Metal cations would usually repel each other, but hold together as all are attracted to the electrons.
- The metal cations are arranged within a lattice (a tightly packed regular arrangement):



Let's have a look at a question together!

Question 2 (3 marks) **Walkthrough.**

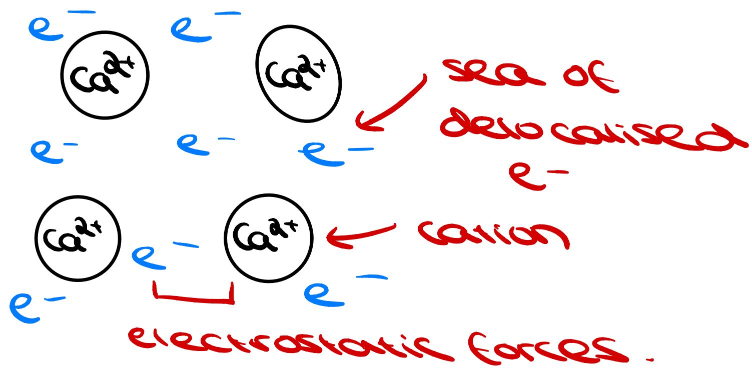
Draw the metallic bonding structure if nine Lithium (Li) atoms were to metallic bond together.



Your turn!

Question 3 (3 marks)

Draw the metallic bonding structure if 4 Calcium (Ca) atoms were to metallic bond together.



Key Takeaways

- Metallic bonding is caused by electrostatic attraction between metal cations and the electrons lost.
- The lost electrons group together in a **'sea of delocalised electrons'**.
- The metal cations are arranged within a **lattice**.

Space for Personal Notes

Section B: Properties of Metals

Sub-Section: Conductivity of Electricity

Discussion: What is electricity?

movement of charged particles → e⁻

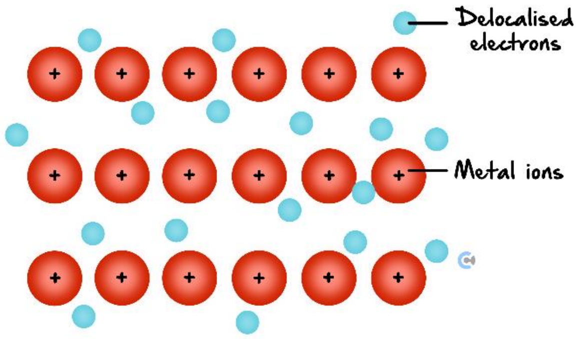
Electricity

- Energy resulting from the existence of charge particles (such as electrons), either statically as an accumulation of charge or dynamically as a current.

Discussion: Can the electrons move freely about in a metallic bonded structure?

→ delocalise e⁻

Exploration: Delocalised Electrons



- Since these electrons are delocalised, that means they are free moving
- As such, metals are [good]/[poor] conductors of electricity.

Try a question!

Question 4 (1 mark)

Which one of the following best explains why metals can conduct electricity in a solid state?

A. Ions can move easily through the lattice.

B. All electrons can move easily through the lattice.

C. Outer-shell electrons can move easily through the lattice.

D. Ions and electrons can move easily through the lattice.

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Sub-Section: Thermal Conductivity

Thermal Conductivity

- Metals are also good conductors of heat (thermal energy).
  - Electrons can easily transfer the thermal energy throughout the metal, as they are free to move.

NOTE: Thermal conductivity is not commonly tested!

Try a question!

Question 5 (3 marks)

Explain how the [metallic bonding model links] to a metal's ability to [conduct heat] and [electricity].

① ① ①

• metallic bonding → cations in a sea of delocalised e⁻ via electrostatic forces.

• these e⁻ are free moving, allowing electricity to move through the lattice.

• these e⁻, also allow heat to be dispersed via the lattice.

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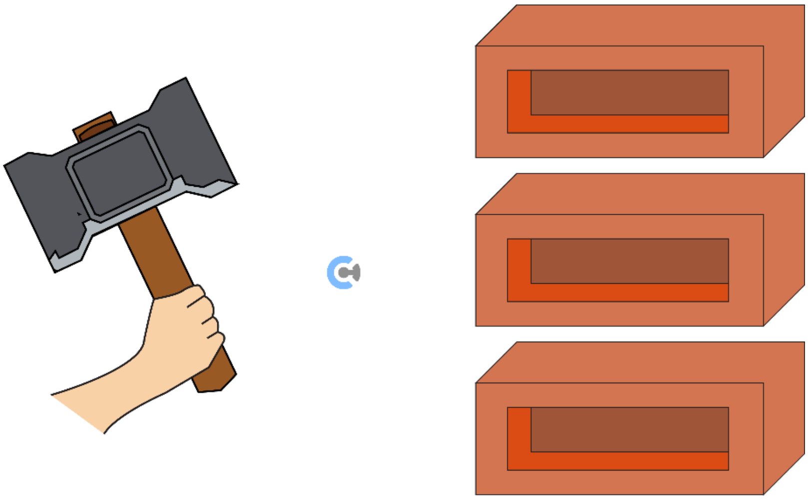
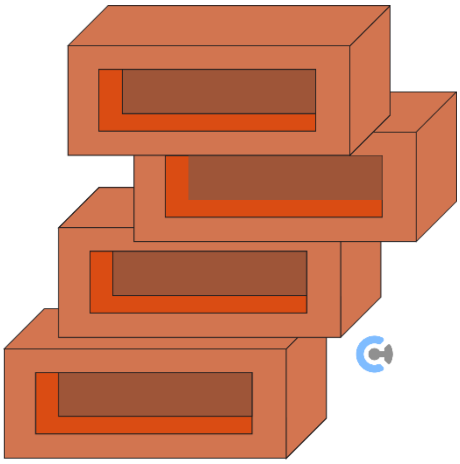
Sub-Section: Malleability

Analogy: Bricks

- Consider some **bricks being hit by a hammer:**



What will happen to the bricks?



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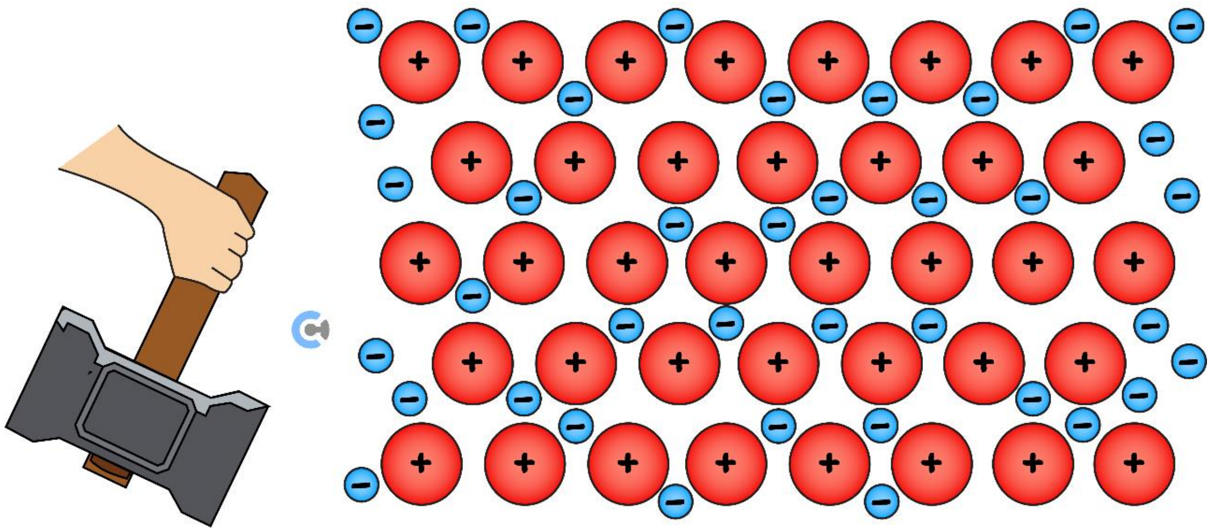
Exploration: Malleability

- Consider a metallic bonding structure comprised of a metal lattice of cations with a sea of delocalised electrons:
  - What happens if the structure is struck by a hammer?

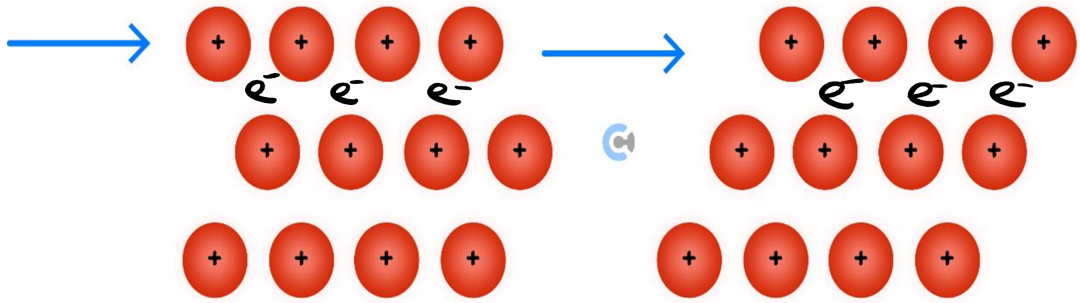


- The metal structure/shape **[does]** / **[does not]** change. (Label Above)
- There **[is]** / **[is not]** electrostatic attraction between the cations and electrons.
- Thus, the metallic bonding **[is]** / **[is not]** intact.
- As such, the metal itself **[is]** / **[is not]** broken or cracked.

Definition

Malleability

- Metals are malleable they can shape when hit, but will not break
- The force causes metal ions to move past each other.
- Ion layers are still together due to electrostatic attraction between the metal ions and delocalised electrons.



NOTE: We also say that metals are ductile. This is due to very similar reasoning. Ductility talks about a substance's ability to be drawn into a wire

Question 6 (2 marks)

Explain why metals are malleable and ductile.

• metals have a sea of delocalised e^-
· these e^- are able to shift when the lattice is altered, maintain the electrostatic force of attractions
∴ the shape changes without breaking

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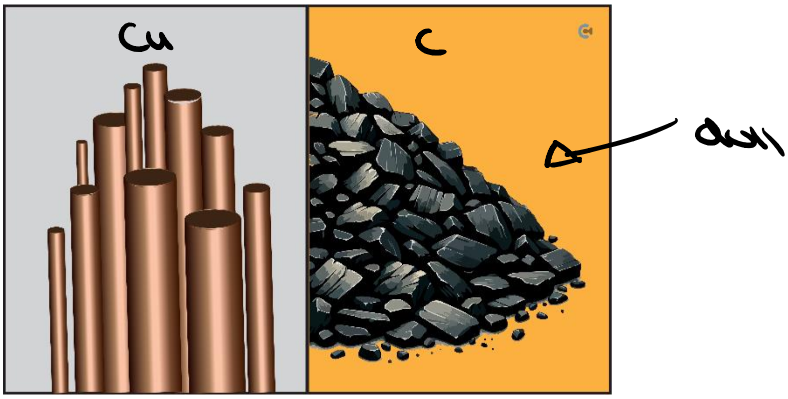
Sub-Section: Metal Appearance

Exploration: Metal Appearance

- Appearance of metals compared to the appearance of non-metals:

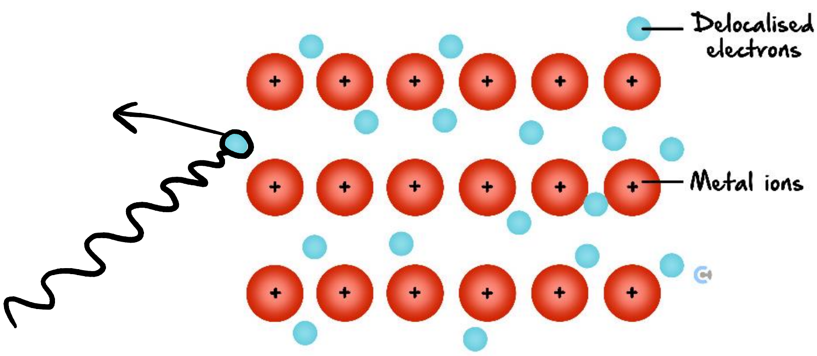


- What are the differences in terms of appearance between metals and non-metals?

lustrous

- Metals are lustrous, which means that they reflect light

- Why is this the case?



- The 'free' electrons can absorb light energy and vibrate and reflect the energy back.

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Try some questions!

Question 7 (1 mark)

Which one of the following properties is **not** typical of most metals?

A. High density

B. Brittle

C. High boiling point

D. High electrical conductivity in solid state

Question 8

You are given the following clues about four unknown metals, A, B, and C:

Metal A has one valence electron.

Metal B has a larger atomic radius than A.

Metal C has more delocalised electrons than the other three metals.

Given that the metals are either Potassium, Magnesium, or Sodium, state the identities of each of the metals.

Question 9 (1 mark) **Additional Question.**

Which of the following is true regarding metals?

A. Metals are typically soft.

B. Metals can conduct electricity as they have free-moving cations.

C. Delocalised electrons exist in every compound containing a metal.

D. Delocalised electrons arise from metal atoms becoming stable.

Key Takeaways

- ☑ Due to free moving charges - delocalised electrons - metals are good **conductors of electricity and heat.**
- ☑ When struck, the lattice structure of a metal merely shifts, but remains intact due to electrostatic attraction between the cations and delocalised electrons, making them **malleable and ductile.**
- ☑ Metals are **lustrous**, as the delocalised electrons are able to reflect light.

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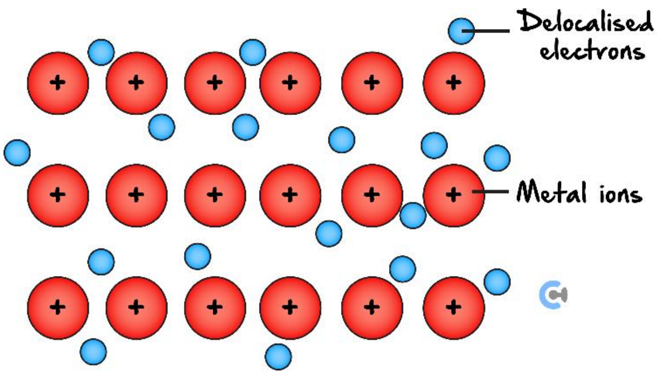
Section C: Strength of Metallic Bonding

Context

- Let's compare the strength of metals and their respective metallic bonding.
- Metallic bonding is shown below:



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Sub-Section: Metallic Bonding Strength: Cations with Different Charges

Discussion: Is this electrostatic attraction between the metal cations and the negative electrons a strong or weak attraction?

(+) - - - - - - - - (−)
↑ strong

Exploration: Strength of Metallic Bonding

- Due to strong electrostatic attraction, metals are very hard, as the metal cations are held tightly together in the metallic lattice.
- Leads to metals being packed together tightly, making them very dense.

Let's look at a question together!

Question 10 (3 marks) **Walkthrough.**

Explain whether Magnesium (Mg) or Sodium (Na) has a higher melting point.

• Na → group 1 → donate 1e^-
• Mg → group 2 → donate 2e^-
∴ Mg lattice has more e^- → more electrostatic forces → ∴ harder to weaken
∴ ↑ m.p

NOTE: Melting point only requires intermolecular bonds to be weakened.

- Boiling point only requires intermolecular bonds to be completely broken.

Sample Response: Melting/Boiling Point

- When explaining what substance has a higher or lower melting or boiling point, be sure to cover:
  - Which substance has stronger bonding.
    - Explain why the substance has stronger/weaker bonding.
  - If one of the substances has stronger bonding, more thermal energy is required to vibrate and weaken (for melting point) / break (for boiling point) the bonds.
  - Leading to a higher melting/boiling point.

Try one yourself!

Question 11 (3 marks)

Explain which metal has a higher boiling point out of Lithium and Calcium.

• Lithium forms a +1 ions → donates 1e⁻
• Calcium forms a +2 ion → donates 2e⁻
∴ Calcium's lattice has more e⁻, & more electrostatic forces meaning more energy is needed to break the bonds → ∴ ↑ B.P

NOTE: The strength of the metallic bonds depends on the charges of the metal cations. A greater cation charge leads to ______________________ metallic bonding.

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Sub-Section: Comparing Metallic Bonding Down a Group

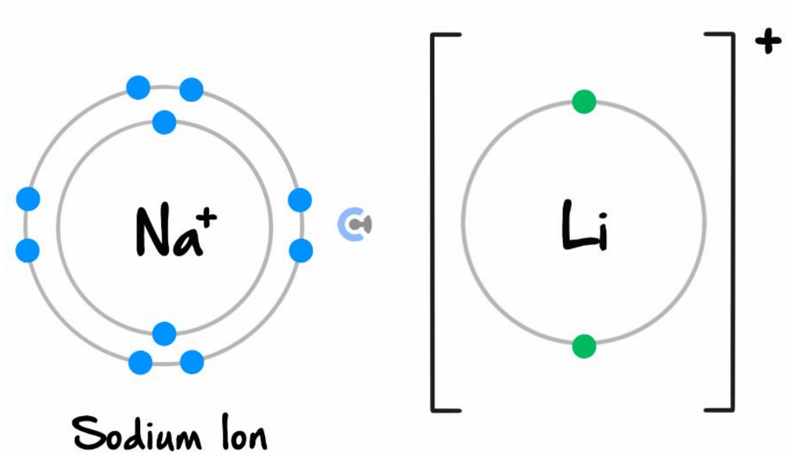
What if two metals form the same charge when ionised?

Exploration: Metallic Bonding Down a Group

- Consider Lithium (Li) and Sodium (Na).
- What is the charge of Lithium and Sodium?

Li^+ Na^+

- What is the difference between Lithium (period 2) and Sodium (period 3)?



- The cation that is closer to its delocalised electrons is [Sodium] / [Lithium].
- The [Sodium] / [Lithium] cation will have stronger electrostatic attraction to a lone electron.
  - As such, lithium has stronger metallic bonding.
  - Thus, it will have a higher melting/boiling point.

Definition

Metallic Bonding Strength

- The strength of the metallic bonds depends on the charges of the metal cations.
- A greater cation charge leads to stronger metallic bonding.
- When comparing metals from the same group, metals with smaller atomic radii will have greater electrostatic attraction, and therefore, stronger metallic bonding.

Try some questions!

Question 12 (3 marks)

Explain whether Potassium (K) or Sodium (Na) has a higher melting point.

• Na has one less e⁻ shell → smaller atomic radius
• ∴ Na^+ cation gets closer to e⁻ & thus makes stronger electrostatic forces.
• Due to this Na^+ has a higher M.P

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Question 13 (4 marks)

Explain whether Barium (Ba) or Francium (Fr) has a higher melting point.

• Barium has 6e⁻ shells → 2 valence e⁻

• Francium has 7e⁻ shells → 1 valence e⁻

As Barium has more e⁻, it forms more electrost forces. It also forms stronger bonds → get closer due to its smaller atomic radius.

• ∴ Barium needs more to weaken bond

∴ ↑ m.p

Key Takeaways

- Due to the strong electrostatic attraction between metal cations and the sea of delocalised electrons, metallic bonding is strong.
- This gives rise to metals being hard, strong, and dense.
- The strength of the metallic bonds depends on the charges of the metal cations. A greater cation charge leads to stronger metallic bonding.
- When comparing metals from the same group, metals with smaller atomic radii will have greater electrostatic attraction, and therefore, stronger metallic bonding.
- Melting point only requires intermolecular bonds to be weakened.
- Boiling point only requires intermolecular bonds to be completely broken.

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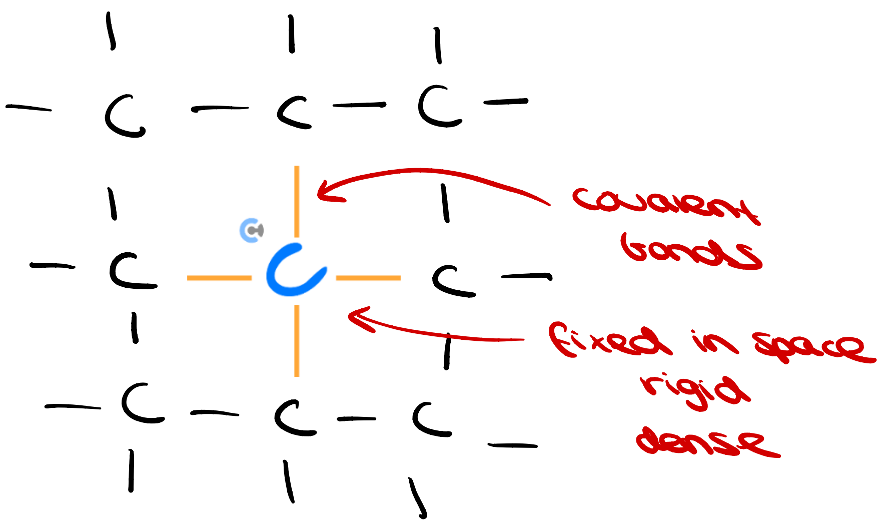
Section D: Covalent Lattices

Context

- Let's look at covalent lattices in Carbon.
- Carbon is a unique molecule because it can bond with itself in multiple ways, unlike most non-metals.
- How many covalent bonds can Carbon form?

Exploration: Covalent Lattices

- As such, Carbon can bond with itself in the following way:



Discussion: What is this Carbon structure known as?

diamond

Discussion: Do diamonds have high or low melting/boiling points?

[High] / [Low] Melting Point

Extension: Sublimation Point of Diamonds

- Diamonds can't 'melt' and turn into a liquid as the bonds inside diamonds need to be weakened.
- As diamonds are made of strong covalent bonds, they are either holding the diamond in place or not present at all.
- Diamonds do not have melting or boiling points, rather, they have sublimation.
- Sublimation point is where a substance sublimes or turns from a solid directly to a gas.

Discussion: Can diamonds conduct electricity?

[Yes] / [No]

Exploration: Can diamonds conduct heat?

[Yes] / [No]

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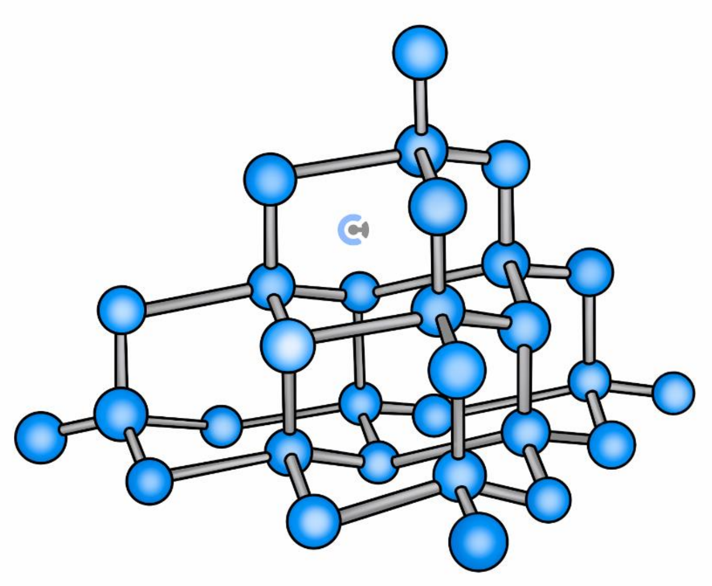
Definition

Diamonds

- Alternative Name: allotrope of Carbon.



- Strength of Diamonds: [High] / [Low]
- Melting Point of Diamonds: [High] / [Low]
- Conductivity of Electricity: [High] / [Low]
- Conductivity of Heat: [High] / [Low]

Definition

Allotrope

- Definition:
  - One of two or more different ways in which an element can exist by itself.
- **Example:** Oxygen can exist in two allotropes: O_2 and O_3.

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Oxygen gas

ozone

Your turn!

Question 14 (4 marks)

Explain each of the following properties of Diamonds.

a. Its high strength. (2 marks)

Diamond has C atoms that form 4 strong covalent bonds in each direction → lots of energy needed to break these bonds.

b. Its inability to conduct electricity. (2 marks)

no free moving e^-

Question 15 (1 mark) **Additional Question.**

What type of bond exists between the carbon atoms in a diamond?

A. Ionic Bond

B. Metallic Bond

C. Covalent Bond

D. Hydrogen Bond

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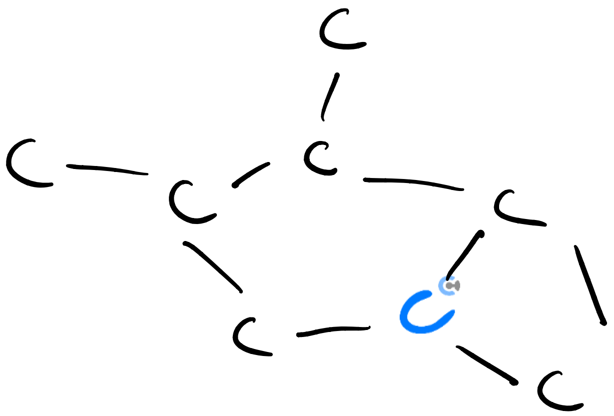
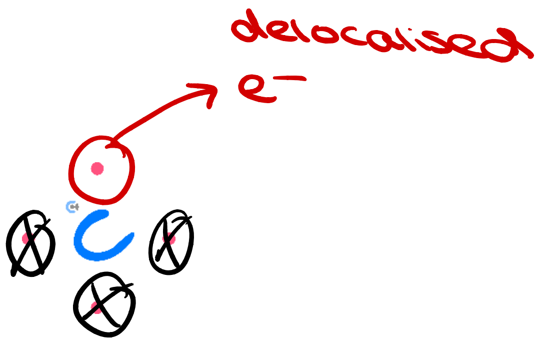
Sub-Section: Allotropes of Carbon

Exploration: Another Allotrope of Carbon

- Carbon can form another allotrope which is in the following structure:



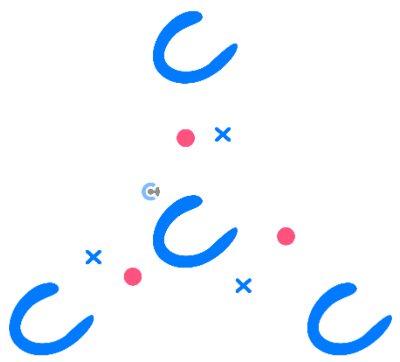


- Name of this carbon allotrope: graphite

NOTE: Carbon can form three covalent bonds with itself instead of four, which generally happens when the Carbon is not under immense pressure and will be pushed tightly together.

ALSO NOTE: The last electron that Carbon has will be shot out and delocalised.

<u>Discussion:</u> What is the shape formed from carbon atoms in graphite?

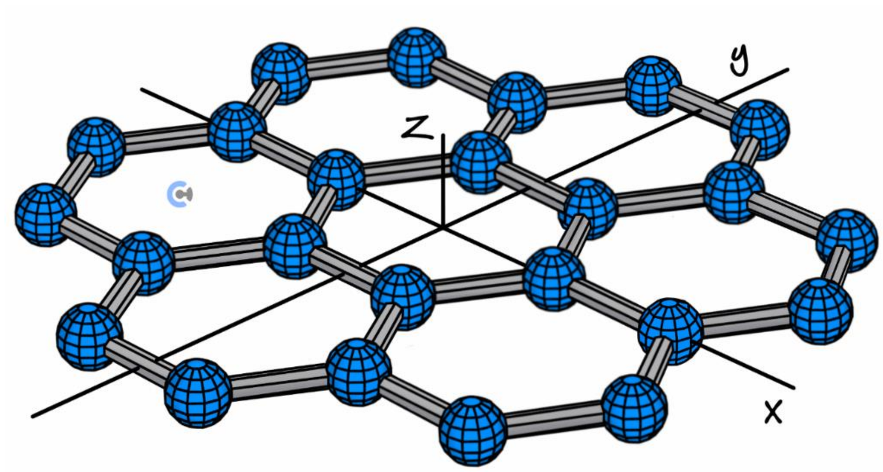


trigonal planar

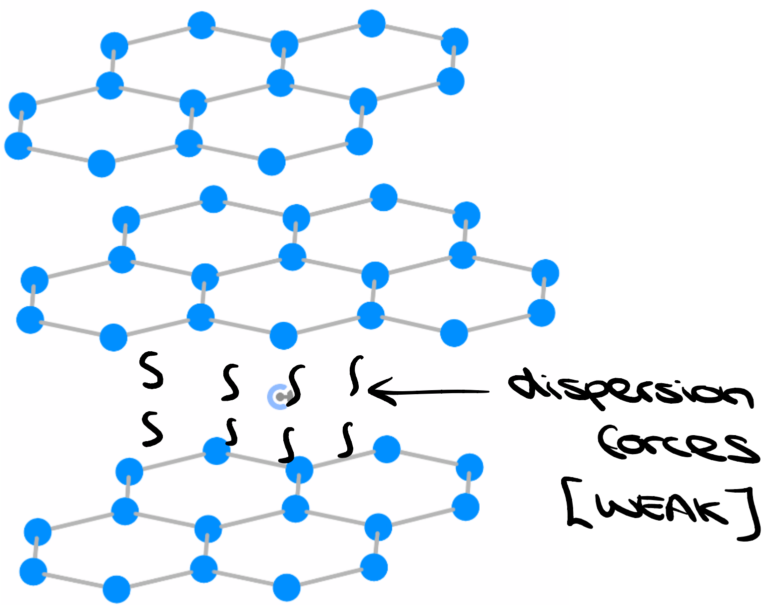
NOTE: Graphite's structure is made of trigonal planar carbons, so the entire structure is **planar**.

ALSO NOTE: This means that graphite's structure can be thought of as being two-dimensional or as a layered covalent structure.

<u>Exploration</u>: Structure of Graphite



- What happens in nature is that, the graphite layers stack on top of each other.



<u>Discussion:</u> What type of intermolecular forces act between each graphite layer?

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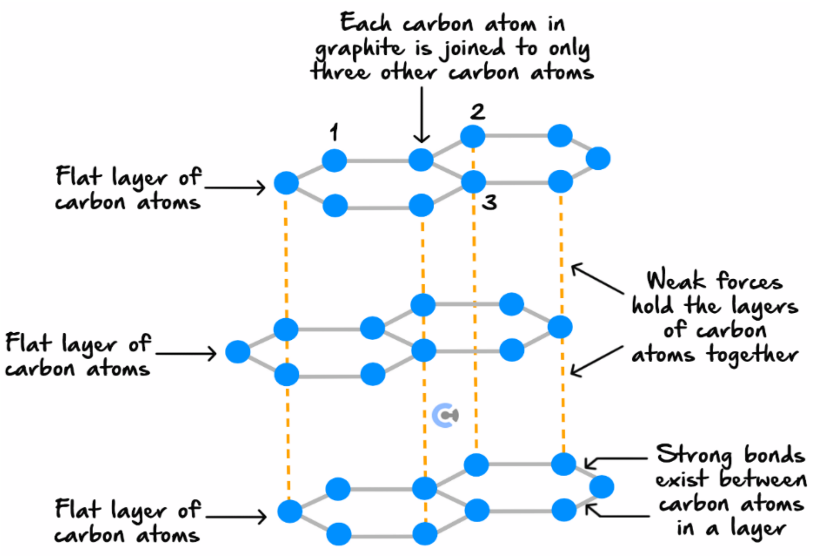
Exploration: Strength of Intermolecular Bonds of Graphite



- Strength of Intermolecular Bonds **within** Graphite Layer: covalent (strong)
- Strength of Intermolecular Bonds **between** Graphite Layers: dispersion (weak)
- If a force is applied **horizontally**, how will graphite act? **[Hard & Rigid] / [Soft & Slippery]**
- If a force is applied **vertically**, how will graphite act? **[Hard & Rigid] / [Soft & Slippery]**

Discussion: Where can graphite be found in real life?

pencils

lubricant

NOTE: As graphite is very soft and slippery in one direction, its structure is exploited in pencil lead for writing.

Exploration: How does graphite allow pencils to 'write'?

- As the pencil is rubbed against a surface, a layer of graphite that is 'slipped' off the pencil lead and is 'applied' to the surface.

Discussion: What is a property of the delocalised electrons in graphite?

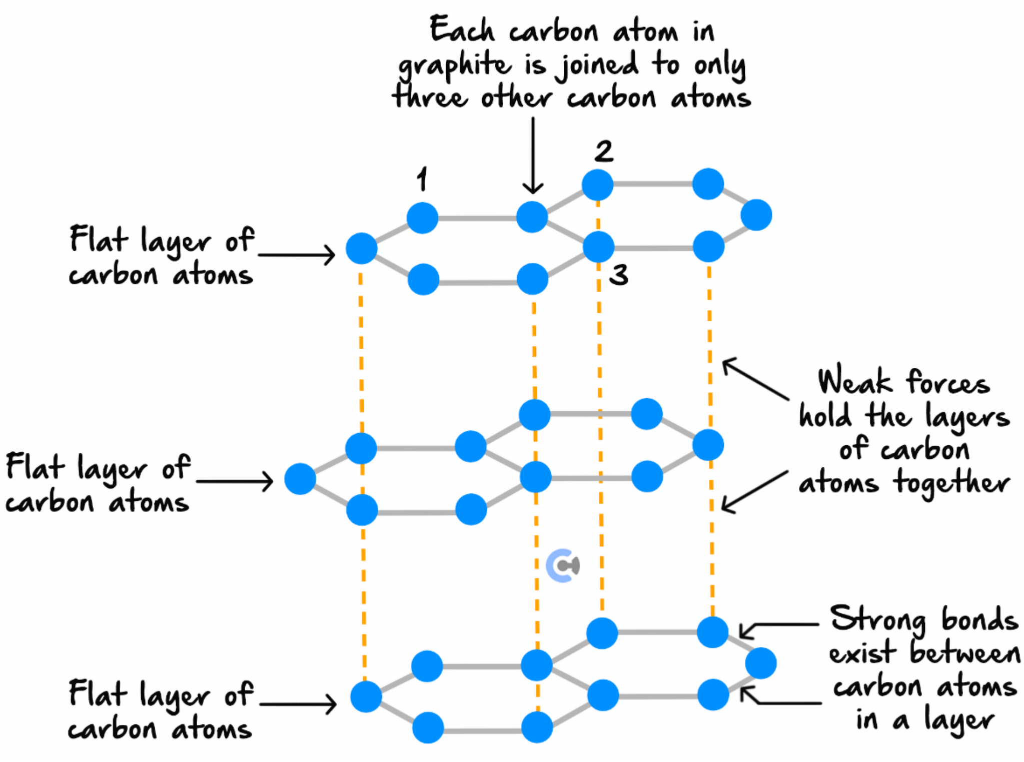
conduct electricity

Exploration: Can graphite conduct heat?

[Yes] / [No]

Graphite

- Another allotrope of carbon, which forms a sea of delocalised electrons.
- Each carbon forms three bonds in a trigonal planar shape.



- Alternative Name: covalent layer lattice.

- **Bonding:**

Within Each Layer	Between Each Layer
Forms Covalent Bonds	Forms Dispersion Forces
Hard & Rigid	Soft & Slippery

- **Conductivity of Electricity: [High] / [Low]**
- **Conductivity of Heat: [High] / [Low]**

Your turn!

Question 16 (1 mark)

What is the structure of graphite?

A. 3D Tetrahedral Lattice

B. Layered Hexagonal Structure

C. Body-Centered Cubic Structure

D. Random Amorphous Structure

Space for Personal Notes

electrode → conducts electricity

Question 17

For each of the following, state whether diamond or graphite is likely to be used.

Use of Material	Material
Jewellery	D
Lubricants	G
Pencil Lead	G
Industrial Saw Blades	D
Drill Bits	D
Electrodes	G

Question 18

Explain each of the following properties of graphite.

a. Its ability to conduct electricity.

→ free moving delocalise e^-

b. Why it is soft and slippery?

→ weak dispersion force b/w layers
→ easily overcome

c. Why does it have a high sublimation point?

Strong covalent bonds holding carbons together, ↑ energy to break bonds.

Question 19 (1 mark)

Graphite can act as a lubricant. Select the alternative that best explains this property.

A. The particles in graphite are not bonded to each other very strongly.

B. The forces between layers of graphite are weak.

C. There are delocalised electrons moving between the layers.

D. The intramolecular bonds in graphite are weak.

Question 20 (1 mark)

Select the correct answer that best explains why diamond and graphite have such high sublimation points.

A. Molecules of Carbon are strongly attracted to each other by covalent bonds.

B. Molecules of Carbon are strongly attracted to each other by strong intermolecular forces.

C. Both have lattice structures with Carbon atoms bonded together by covalent bonds.

D. Both have lattice structures with Carbon atoms bonded together by strong intermolecular forces.

NOTE: Similar to diamonds, graphite cannot melt as it is held together by strong covalent bonds. It instead sublimes directly from a solid to a gas.

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Question 21 (1 mark) **Additional Question.**

What is a primary industrial use of graphite?

A. Jewellry manufacturing.

B. Electrical insulation.

C. Electrode production in batteries and furnaces.

D. Transparent coatings.

Question 22 (1 mark) **Additional Question.**

Which of the following is NOT true about graphite?

A. It conducts electricity.

B. It has high melting and boiling points.

C. It is the hardest naturally occurring substance.

D. It is used as a lubricant.

Extension: Amorphous Forms of Carbon

- Amorphous carbon is the 'regular' state in which Carbon exists, usually in wood, coal, etc.
- It has no consistent structure and contains irregularly packed, tiny crystals or graphite and other non-uniform arrangements.

Study Design: Covalent Substances

The structure and bonding of diamond and graphite that explain their properties (including heat conductivity and electrical conductivity and hardness) and their suitability for diverse applications.

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Contour Check

Learning Objective: [1.3.1] - Explain the metallic bonding model

Key Takeaways

- Metallic bonding is caused by electrostatic forces between metal cations and the electrons lost.
- The lost electrons group together in a 'sea of delocalised electrons'.
- The metal cations are arranged within a lattice.

Learning Objective: [1.3.2] - Identify properties of metals (High MP/BP, electrical & thermal conductivity, malleability & ductility, lustre)

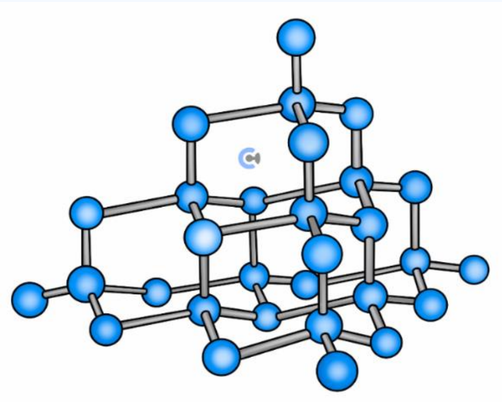
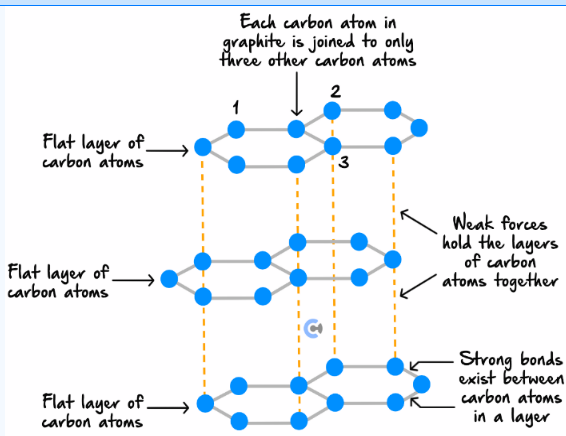
Key Takeaways

- Metals are **[good]** / **[bad]** conductors of electricity and heat due to the presence of free moving e^-.
- Metals are malleable and ductile when struck, the lattice structure of a metal change shape, but not break due to electrostatic attraction between the cations and delocalised electrons.
- As delocalised electrons can reflect light, metals are lustrous.
- Metallic bonding is **strong, hard, and dense** due to the strong electrostatic forces between metal cations and the sea of delocalised electrons.
- A **[higher]** / **[lower]** charge of metal results in stronger metallic bonding.
- Within the same group, metals with smaller atomic radii will have **[greater]** / **[weaker]** electrostatic attraction, and therefore, **[stronger]** / **[weaker]** metallic bonding.
- Melting point → Intermolecular bonds are weakening
- Boiling point → Intermolecular bonds are breaking.

Learning Objective: [1.3.3] - Explain the covalent lattice structures bonding & properties of diamond and graphite

Key Takeaways

- Diamond and Graphite are both allotropes of carbon.

Diamonds	Graphite
	
Strength: **[High]** / **[Low]**	**Strength:** Vertical Strength: **[High]** / **[Low]** as it bonds via covalent bonds Horizontal Strength: **[High]** / **[Low]** as it bonds via dispersion forces
Melting Point: **[High]** / **[Low]**	Melting Point: **[High]** / **[Low]**
Conductivity of Electricity: **[High]** / **[Low]**	Conductivity of Electricity: **[High]** / **[Low]**
Conductivity of Heat: **[High]** / **[Low]**	Conductivity of Heat: **[High]** / **[Low]**

Key Takeaways

- Metals are **[good] / [bad]** conductors of electricity and heat due to the presence of ____.
- Metals are malleable and ductile when struck, the lattice structure of a metal __________________________, but ____________________________ due to electrostatic attraction between the cations and delocalised electrons.
- As delocalised electrons can reflect light, metals are ________________.
- Metallic bonding is **strong, hard, and dense** due to the strong _______________________________ between metal cations and the sea of delocalised electrons.
- A **[higher] / [lower]** charge of metal results in stronger metallic bonding.
- Within the same group, metals with smaller atomic radii will have **[greater] / [weaker]** electrostatic attraction, and therefore, **[stronger] / [weaker]** metallic bonding.
- Melting point → Intermolecular bonds are ________________.
- Boiling point → Intermolecular bonds are __________________________________.

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