▶ Video explanation (YouTube Short)

Interstitial Compounds and Alloys: How Transition Metals Get Harder

Pure iron is fairly soft and bends. Add less than 2 % carbon and it becomes steel, strong enough for bridges and rails. These notes explain how small atoms in the gaps of a metal (interstitial compounds) and atoms of similar size mixed in (alloys) change a transition metal (NCERT 4.3.13 and 4.3.14).

1. Why a pure metal bends (a simple model)

- In a metal, atoms are packed in regular **layers**.
- When a force is applied, one layer can **slide over another**; this is why pure metals are malleable and ductile and bend easily.
- Anything that **blocks the sliding** makes the metal harder.

> **Note:** this is a school-level model; in real crystals the sliding happens through defects called dislocations, but the idea (blocking the slip makes a metal harder) is the same.

2. Interstitial compounds (NCERT 4.3.13)

- **Interstitial compounds** are formed when **small atoms like H, C or N are trapped inside the crystal lattices of metals** (in the empty spaces, or *interstices*, between the metal atoms).
- They are usually **non-stoichiometric** and are **neither typically ionic nor covalent**.
- Examples: **TiC, Mn_4N, Fe_3H, $VH_{0.56}$, $TiH_{1.7}$**. These formulas do not correspond to any normal oxidation state of the metal (V cannot be +0.56!).

Properties

Property	Detail
High melting points	higher than those of the pure metals (e.g. Ti ≈ 1668 °C, TiC ≈ 3160 °C)
Very hard	some borides approach diamond in hardness
Metallic conductivity	they still conduct electricity
Chemically inert	they hardly react

Steel is a familiar case of the same idea: carbon atoms in the gaps of iron (and iron carbide) block the sliding layers, so steel is much harder than pure iron.

3. Alloys (NCERT 4.3.14)

- An **alloy** is a blend of metals prepared by mixing the components.
- Many alloys are **homogeneous solid solutions**: atoms of one metal are distributed **randomly** among the atoms of the other (substitution).

- Such alloys form when the **metallic radii are within about 15 %** of each other.
- Transition metals have **similar radii** (Table 4.2: Cr 129, Fe 126, Ni 125, Cu 128 pm), so they form alloys readily.
- The alloys are **hard** and often have **high melting points**.

Alloy	Made from	Use
steels, stainless steel	Fe with Cr, V, W, Mo, Mn (stainless: Fe + Cr + Ni)	tools, utensils, construction
brass	Cu + Zn	fittings, instruments
bronze	Cu + Sn	statues, bearings, medals

Brass and bronze are alloys of a transition metal with a non-transition metal.

4. Worked examples

Example 1

Q. Can Fe (126 pm) and Cr (129 pm) form a substitutional alloy easily? **A.** Difference = (129 − 126)/126 × 100 ≈ 2.4 %, well within 15 %: yes.

Example 2

Q. Cu = 128 pm, Zn = 137 pm. Within 15 %? **A.** (137 − 128)/128 × 100 ≈ 7 %: yes, they form brass.

Example 3

Q. Why is $VH_{0.56}$ called non-stoichiometric? **A.** H atoms occupy only some of the gaps, so the ratio is not a simple whole number and does not match a normal oxidation state of V.

Example 4

Q. Why is TiC used for cutting tools? **A.** As an interstitial compound it is very hard, has a very high melting point and is chemically inert.

5. Common mistakes

- ✗ "An alloy is a compound with a fixed formula." ✓ It is a blend / solid solution; composition can vary.
- ✗ "Interstitial compounds are ionic." ✓ They are neither typically ionic nor covalent and keep metallic conductivity.
- ✗ "Adding carbon makes iron softer." ✓ It blocks sliding layers and makes it harder (steel).

6. Key takeaways

- Small atoms (H, C, N) trapped in gaps → interstitial compounds: hard, high-melting, conducting, inert, non-stoichiometric.
- Atoms of similar size (within ~15 %) mix randomly → alloys; transition metals do this readily.
- Both make a metal harder.

Practice questions

1. (MCQ) Which atom can form an interstitial compound with a metal? (a) Na (b) C (c) Cl (d) K
2. (MCQ) Interstitial compounds are: (a) ionic (b) covalent (c) neither typically ionic nor covalent (d) gases
3. (MCQ) Brass is an alloy of: (a) Cu and Sn (b) Cu and Zn (c) Fe and Cr (d) Zn and Sn
4. (MCQ) Alloys form readily when metallic radii differ by less than about: (a) 1 % (b) 15 % (c) 50 % (d) 100 %
5. (Very short) Give two examples of interstitial compounds.
6. (Very short) Name the components of bronze.
7. (Short) State four characteristic properties of interstitial compounds.
8. (Short) Why do transition metals form alloys readily?
9. (Short) What is meant by "non-stoichiometric"? Give an example.
10. (HOTS) Na has a metallic radius of 186 pm and Fe 126 pm. Will they form a substitutional alloy easily? Justify.

Answer key

1. (b) C.
2. (c).
3. (b) Cu and Zn.
4. (b) 15 %.
5. TiC, Mn_4N (also Fe_3H, $VH_{0.56}$, $TiH_{1.7}$).
6. Copper and tin.
7. High melting points (higher than the pure metals); very hard; retain metallic conductivity; chemically inert.
8. Their metallic radii are similar (within about 15 %), so atoms of one can replace atoms of the other in the lattice.
9. The composition does not follow a simple whole-number ratio or a normal oxidation state; e.g. $VH_{0.56}$, $TiH_{1.7}$.
10. No: (186 − 126)/126 × 100 ≈ 48 %, far more than 15 %, so Na atoms cannot easily take Fe's places.

▶ Watch the video explanation