# Unit 7 · Chemical Bonding

**HARDER PRACTICE QUESTIONS · ANSWER KEY**

Full marks 40

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

## 1 Spot the errors

**ANSWER** U · 3

1. Moles are upside down: n = V ÷ 22.4 = 5.6 ÷ 22.4 = **0.25 mol**, not 4.
2. Molar mass is upside down too: M = m ÷ n = 16 ÷ 0.25 = **64 g/mol**. His two mistakes cancel, so 64 comes out right by luck.
3. Vapor density is wrong: molecular mass = 2 × VD, so VD = 64 ÷ 2 = **32**, not 128. (It could be sulphur dioxide, $SO_2$.)

**MARKING SCHEME**

✓ n = 5.6 ÷ 22.4 = 0.25 mol.
✓ M = m ÷ n = 16 ÷ 0.25 = 64 g/mol: the two inverted steps cancel.
✓ VD = M ÷ 2 = 32.

## 2 Reading the table

**ANSWER** A · 4

i. First $\pi$: 614 − 347 = **267 kJ/mol**. Second $\pi$: 839 − 614 = **225 kJ/mol**.
ii. 3 × 347 = 1,041 kJ/mol, against the real 839: **202 kJ/mol** too high. A triple bond is 1 $\sigma$ + 2 $\pi$, and a $\pi$ bond, a smaller sideways overlap off the axis, is weaker than a $\sigma$ bond.
iii. 154 − 134 = **20 pm** for the first and 134 − 120 = **14 pm** for the second: smaller.
iv. At their $\pi$ **bonds**. The table shows a $\pi$ bond adds less energy (267 or 225 kJ/mol) than the 347 kJ/mol of the $\sigma$ bond, so it is the easier one to break, and alkanes have none.

**MARKING SCHEME**

✓ 267 kJ/mol and 225 kJ/mol.
✓ 1,041 against 839, so 202 kJ/mol too high, because $\pi$ bonds are weaker than $\sigma$ bonds.
✓ 20 pm then 14 pm: the shortening gets smaller.
✓ They react at the $\pi$ bonds, which add less energy than the $\sigma$ bond's 347 kJ/mol.

## 3 How much air?

**ANSWER** A · 4

(The 14 kg is a round figure for the question, and real LPG is propane and butane.)

i. M = 3 × 12 + 8 = 44 g/mol. n = 14,000 ÷ 44 = 318 mol. V = 318.2 × 22.4 ≈ **7,130 L**.
ii. Oxygen = 5 × 7,127 ≈ **35,600 L**. Air = 35,636 ÷ 0.21 ≈ **170,000 L**, or 170 $m^3$.
iii. A room is 5 × 4 × 3 = 60 $m^3$, so 170 ÷ 60 ≈ **about 3 rooms** of air.
iv. With too little air, the flame burns yellow and sooty and makes carbon monoxide, which stops the blood carrying oxygen.

**MARKING SCHEME**

✓ 318 mol of propane, about 7,130 L.
✓ About 35,600 L of oxygen and 170,000 L of air.
✓ About 3 rooms (170 ÷ 60).
✓ Too little air gives carbon monoxide.

## 4 Predict, then explain

**MARKING SCHEME** A · 3

✓ 10 L of hydrogen uses 5 L of oxygen (2 : 1), leaving 5 L of oxygen.
✓ It gives 10 L of steam.
✓ 20 L before and 15 L after.



Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

## 5 Electron book-keeping

**ANSWER** U · 4

i.

| Particle | Outer electrons | Pairs | Shared pairs | Lone pairs |
|---|---|---|---|---|
| $NH_4^+$ | $5 + 4 - 1 = 8$ | 4 | 4 | 0 |
| $H_3O^+$ | $6 + 3 - 1 = 8$ | 4 | 3 | 1 |
| $O_3$ | 18 | 9 | 3 | 6 |
| $SO_3$ | 24 | 12 | 4 | 8 |

ii. $NH_4^+$ 1, $H_3O^+$ 1, $O_3$ 1, $SO_3$ 2.

iii. Yes. Before, boron has 3 shared pairs with fluorine: **6 electrons**, with an empty orbital. Ammonia's lone pair makes it **8**.

**MARKING SCHEME**

- ✓ $NH_4^+$ and $H_3O^+$ rows: 8 electrons, 4 pairs, split 4 + 0 and 3 + 1.
- ✓ $O_3$ and $SO_3$ rows: 18 (3 + 6) and 24 (4 + 8).
- ✓ Coordinate bonds 1, 1, 1, 2.
- ✓ Boron goes from 6 electrons, with an empty orbital, to 8.

## 6 Which explanation fits the evidence?

**ANSWER** HA · 3

**Nirajan's.** Sneha's idea predicts two different lengths, 148 pm and 121 pm, but both bonds measure 128 pm, between the two. The same length for both means neither is purely a single or a double bond, so the molecule is a resonance hybrid of the drawings. (A coordinate bond is indeed like any covalent bond once formed, but that doesn't decide its length here.)

**MARKING SCHEME**

- ✓ Nirajan's explanation.
- ✓ Sneha's predicts two different lengths, but both are 128 pm.
- ✓ 128 pm lies between 148 pm and 121 pm, so the bonds are a blend: a resonance hybrid.

## 7 Design a fair test

**ANSWER** A · 4

i. Battery, bulb and the two rods in series, the rods dipping into the liquid.

ii. Any three: the same battery and bulb; the same depth and distance apart of the rods; the same strength of each solution; clean rods each time.

iii. Sugar water and ethanol in water: **no light**, since they are covalent molecules that give no ions. Salt water: **lights**, since its ions are free to move. Hydrochloric acid: **lights**, although HCl is covalent, because its polar molecules react with water to form ions.

iv. Test the water alone (a control), and use distilled water if it conducts.

**MARKING SCHEME**

- ✓ A series circuit with the rods dipping in the liquid.
- ✓ Any three things kept the same.
- ✓ Sugar and ethanol no; salt yes; HCl yes, because it forms ions with water.
- ✓ Test the water alone as a control.

## 8 Most atoms

**ANSWER**

Moles of atoms = moles of molecules × atoms in a molecule.

- $H_2O$: $9 \div 18 = 0.5$ mol, $\times 3 =$ **1.5 mol of atoms**.
- $O_2$: $8 \div 32 = 0.25$ mol, $\times 2 =$ **0.5**.
- $NH_3$: $11.2 \div 22.4 = 0.5$ mol, $\times 4 =$ **2**.
- $CH_4$: $4 \div 16 = 0.25$ mol, $\times 5 =$ **1.25**.
- $CO_2$: $3.011 \times 10^{23} \div 6.022 \times 10^{23} = 0.5$ mol, $\times 3 =$ **1.5**.



Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

Order: **ammonia > water = carbon dioxide > methane > oxygen.** A · 4

**MARKING SCHEME**

- ✓ Moles of molecules: 0.5, 0.25, 0.5, 0.25, 0.5.
- ✓ Multiplied by the atoms in a molecule.
- ✓ Moles of atoms: 1.5, 0.5, 2, 1.25, 1.5.
- ✓ The order, with water and carbon dioxide equal.

## 9 Which gas is it?

**ANSWER** A · 3

Molecular mass = $2 \times 15 = \mathbf{30}$.
Carbon: 80% of 30 = 24, so $24 \div 12 = 2$ atoms. Hydrogen: $30 - 24 = 6$, so 6 atoms. The formula is $\mathbf{C_2H_6}$ (ethane).

**MARKING SCHEME**

- ✓ Molecular mass = $2 \times$ VD = 30.
- ✓ 24 of the 30 is carbon: 2 atoms.
- ✓ 6 hydrogen atoms: $C_2H_6$.

## 10 Correct the misconceptions

**ANSWER** U · 3

1. Boiling doesn't break O–H bonds. It only separates the molecules, against weak forces; steam is still $H_2O$.
2. A double bond is **1** $\sigma$ **+ 1** $\pi$. Two atoms are joined by only one $\sigma$ bond.
3. When carbon bonds, one 2s electron moves up into the empty 2p orbital, leaving **four** unpaired electrons, and the energy of the two extra bonds more than pays for the move. So it makes four bonds, as in $CH_4$.

**MARKING SCHEME**

- ✓ Boiling only separates the molecules; the O–H bonds aren't broken.
- ✓ A double bond is 1 $\sigma$ + 1 $\pi$.
- ✓ Carbon moves a 2s electron to 2p, so it has four unpaired electrons and makes four bonds.

## 11 Think

**ANSWER** HA · 3

Carbon dioxide is made of separate O=C=O molecules, held to one another only by weak forces, so little energy separates them. Quartz is a **giant covalent** solid: covalent bonds run through the whole crystal, with no separate molecules. So **quartz** has to have its strong covalent bonds broken to melt; carbon dioxide's stay whole when it turns to gas.

**MARKING SCHEME**

- ✓ $CO_2$ is separate molecules with weak forces between them.
- ✓ Quartz is giant covalent, with bonds through the whole crystal.
- ✓ Only quartz needs its covalent bonds broken.

## 12 Make your own

**ANSWER** HA · 2

For example: "0.28 g of a gas fills 0.224 L at STP. What could it be?" n = $0.224 \div 22.4 = 0.01$ mol; M = $0.28 \div 0.01 = 28$ g/mol: it could be nitrogen, $N_2$ ($2 \times 14 = 28$).

**MARKING SCHEME**

- ✓ A question with a mass and a volume at STP that fit a real gas.
- ✓ A correct solution through the moles to the molar mass.


Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

## See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Himalayan Pink Salt** (exhibit): Rock salt is sodium chloride: each sodium atom has given an electron to a chlorine atom, and the NaNand ClOions hold tight.

| Marks by level | Knowledge | Understanding | Application | Higher ability | Total |
|---|---|---|---|---|---|
| **Marks** | 0 | 10 | 22 | 8 | **40** |