# Unit 7 · Chemical Bonding

**HARDER PRACTICE QUESTIONS**

Full marks 40

Write your answers on separate paper. Show your working. H = 1, C = 12, N = 14, O = 16, S = 32. Avogadro number = $6.022 \times 10^{23}$; molar volume at STP = 22.4 L.

## 1 Spot the errors [3]

Find the two mistakes that cancel out and the one that doesn't.

Suman was told that 5.6 L of a gas at STP weighs 16 g, and asked for its molecular mass and vapor density. He wrote:
"Moles = 22.4 ÷ 5.6 = 4. Molar mass = 16 × 4 = **64 g/mol**. Vapor density = 2 × 64 = **128**."

## 2 Reading the table [4]

| Bond | Bond energy (kJ/mol) | Bond length (pm) |
|---|---|---|
| C–C | 347 | 154 |
| C=C | 614 | 134 |
| C≡C | 839 | 120 |

i. How much energy does the first $\pi$ bond add? How much does the second add?
ii. Prajwal says, "A triple bond is three single bonds, so C≡C should be 3 × 347 kJ/mol." How far off is he, and why?
iii. How much shorter is the bond for each extra $\pi$ bond? Is the shortening getting bigger or smaller?
iv. Alkenes (C=C) and alkynes (C≡C) react at one kind of bond, and alkanes (C–C) don't. Which kind, and what in the table shows why?

## 3 How much air? [4]

Take a cooking gas cylinder holding 14 kg of gas, as if it were all propane, $C_3H_8$. It burns as $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. Air is about 21% oxygen by volume. Work with volumes at STP.

i. Find the volume of the propane.
ii. Find the volume of oxygen and of air needed to burn all of it.
iii. Estimate how many rooms of 5 m × 4 m × 3 m hold that much air. (1 $m^3$ = 1,000 L)
iv. Why must a kitchen have fresh air?

## 4 Predict, then explain [3]

Write your prediction first, then explain it.

10 L of hydrogen and 10 L of oxygen are sparked in a strong closed cylinder with a movable piston, and kept at 120 °C, so that water stays as steam: $2H_2 + O_2 \rightarrow 2H_2O$. Predict the total volume of gas before and after, at the same temperature and pressure, and what the gas is made of afterward.

## 5 Electron book-keeping [4]

A molecule's or ion's outer electrons can be counted: add each atom's outer electrons, take off 1 for each + charge.

i. Copy and complete the table. (Outer electrons: H 1, N 5, O 6, S 6)

| Particle | Outer electrons | Pairs | Shared pairs | Lone pairs |
|---|---|---|---|---|
| $NH_4^+$ | | | | |
| $H_3O^+$ | | | | |
| $O_3$ | | | | |
| $SO_3$ | | | | |

ii. In each of them, how many coordinate bonds are there as usually drawn?

iii. Is $H_3N{\rightarrow}BF_3$ possible from the point of view of boron? Boron has 3 outer electrons and each fluorine 7. Count the electrons round boron before and after the bond forms.

## 6 Which explanation fits the evidence? [3]

The usual drawing of ozone is O=O→O. In a real ozone molecule, both O–O bonds are 128 pm long. A single O–O bond is 148 pm and a double one 121 pm.

**Sneha:** "The coordinate bond is just a covalent bond once formed, so the arrow side must be a single bond, 148 pm, and the other a double bond, 121 pm."

**Nirajan:** "The double bond isn't in one place. The molecule is a blend of the drawings with the double bond in each position."

Which one does the evidence support? Why can't the other be right?

## 7 Design a fair test [4]

Rabina wants to test which of these conduct electricity: sugar water, salt water, ethanol in water and hydrochloric acid. She has a battery, a bulb, wires, two carbon rods and beakers.

i. Draw a circuit for the test.

ii. Name three things she must keep the same.

iii. Predict the result for each, with the reason.

iv. Water from a tap might itself let a little current through. How would she check for that?

## 8 Most atoms [4]

Arrange these from the most atoms to the fewest: 9 g of water; 8 g of oxygen gas; 11.2 L of ammonia at STP; 4 g of methane; $3.011 \times 10^{23}$ molecules of carbon dioxide.

## 9 Which gas is it? [3]

A gas made only of carbon and hydrogen has a vapor density of 15, and it is 80% carbon by mass. Find its molecular mass and its formula.

## 10 Correct the misconceptions [3]

The paragraph has three mistakes. Write each mistake and correct it.

Ishwori wrote: "Boiling water breaks its O–H bonds, which is why steam is hydrogen and oxygen. A double bond is two $\sigma$ bonds. Since carbon has only two unpaired electrons in its ground state, it can only ever make two bonds."

## 11 Think [3]

Carbon and silicon are both in group 14, and their oxides have similar-looking formulas, $CO_2$ and $SiO_2$. Yet carbon dioxide is a gas, and quartz, $SiO_2$, melts at about 1,700 °C. Explain the difference, and predict which of them would need its covalent bonds broken in order to melt or boil.

## 12 Make your own [2]

Write a “Which gas is it?” question of your own that a friend can solve with $n = m \div M$ and $n = V \div 22.4\ L$, with an answer that is a real gas from this unit. Solve it.