

Exercise walk-through

Resonance and Formal Charge ■ 2.6

eXercise

You must be able to

- draw **resonance** 共振 structures when more than one valid Lewis diagram exists
- calculate **formal charge** 形式电荷 = (valence e^-) - (lone e^-) - $\frac{1}{2}$ (bonding e^-)
- use formal charge to choose the best structure

Method — Resonance

When electrons could be placed in more than one equally valid way, the molecule is a **blend** (resonance hybrid) of those structures. In O_3 (ozone) the double bond is shared between both O–O positions, so both bonds are identical.

Method — Formal charge

For each atom,

$$\text{FC} = (\text{valence } e^-) - (\text{nonbonding } e^-) - \frac{1}{2}(\text{bonding } e^-).$$

Method — A worked formal charge

In CO_2 , the carbon: valence 4, lone 0, bonding 8 (two double bonds):
 $\text{FC} = 4 - 0 - 4 = 0$. Each oxygen: $6 - 4 - 2 = 0$. All zero — a good structure.

Method — Choosing the best structure

The **best** Lewis structure has formal charges **closest to zero**, and any negative formal charge on the **most electronegative** atom. Use this to pick between candidates.

Practice 2.1 ■ 1 mark

Write the formula for formal charge.

Solution 2.1

Worked steps

$$\text{FC} = (\text{valence } e^-) - (\text{nonbonding } e^-) - \frac{1}{2}(\text{bonding } e^-) \quad \text{B1}.$$

Practice 2.2 ■ 2 marks

Find the formal charge on N in NH_4^+ (valence 5, 0 lone electrons, 8 bonding electrons).

Solution 2.2

Method: A worked formal charge

Worked steps

$$\text{FC} = 5 - 0 - \frac{1}{2}(8) = 5 - 4 = +1 \quad \text{M1} \quad \text{A1}.$$

Practice 2.3 ■ 1 mark

What does it mean that ozone O_3 has resonance structures?

Solution 2.3

Method: Resonance

Worked steps

The molecule is a blend (hybrid) of the equivalent structures, not switching between them **B1**.

Exam-style 3.1 ■ 1 mark

The preferred Lewis structure has formal charges that are

- A** as large as possible
- B** as close to zero as possible
- C** all positive
- D** all on carbon

Solution 3.1

Method: Choosing the best structure

- A as large as possible
- B as close to zero as possible
- C all positive
- D all on carbon



Worked steps

B — formal charges as close to zero as possible.

Exam-style 3.2 ■ 2 marks

In one resonance structure of NO_3^- , an oxygen has 6 nonbonding electrons and 2 bonding electrons (a single bond).

- (a) Find the formal charge on that oxygen.
- (b) State what the true structure looks like given resonance.

Solution 3.2

Method: A worked formal charge

Worked steps

(a) $FC = 6 - 6 - \frac{1}{2}(2) = 6 - 6 - 1 = -1$ **M1** **A1**. (b) The real ion is a resonance hybrid — the extra bond and charge are spread equally over all three oxygens **B1**.

Exam-style 3.3 ■ 2 marks

Explain why all three N–O bonds in NO_3^- have the same length, using the idea of resonance.

Solution 3.3

Method: Resonance

Worked steps

Resonance spreads the double-bond character equally over all three N–O positions, so each bond is identical (an average of single and double), giving equal lengths

M1 **A1**.