AP CHEMISTRY • EXERCISE SHEET

2.6 Resonance and Formal Charge

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

Objective

Build the skills to answer exam questions on **resonance and formal charge**.

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

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

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.

Formal charge

For each atom,

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

A worked formal charge

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

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.

2 Practice

Now apply the methods above.

2.1 Write the formula for formal charge. [1]

2.2 Find the formal charge on N in NH_4^+ (valence 5, 0 lone electrons, 8 bonding electrons). [2]

2.3 What does it mean that ozone O_3 has resonance structures? [1]

3 Exam-style questions

3.1 The preferred Lewis structure has formal charges that are [1]

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

3.2 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. [2]

(b) State what the true structure looks like given resonance. [1]

3.3 Explain why all three N–O bonds in NO_3^- have the same length, using the idea of resonance. [2]

4 Go further

You are now ready for the real exam questions on this subtopic:

- work through the **2.6 Resonance and Formal Charge** lesson on the **Learn** page;
- read the **Resonance and Formal Charge** section of the AP Chemistry handout on the **Know** page.

Solutions

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

2.2 FC = $5 - 0 - \frac{1}{2}(8) = 5 - 4 = +1$.

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

3.1 B —formal charges as close to zero as possible.

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

3.3 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.