ExamFitter

examfitter.com · Free AP Chemistry quizzes, revision notes and worksheets

Topic 2.6: Resonance and Formal Charge

Worksheet · AP Chemistry

Unit 2 · Compound Structure and Properties

On ExamFitter.com: Topic 2.6 Revision Notes · Topic 2.6 Quiz · Previous Worksheet: Topic 2.5 · Next Worksheet: Topic 2.7 · Unit 2: All Topics · AP Chemistry Home

How to Use This Worksheet

Work through the sections in order. Section A checks the ideas, Section B builds fluency with formal charge audits and average bond orders, and Section C mixes everything the way an exam would.

For every structure, audit in the same fixed order: count the total valence electrons, describe the bonds and lone pairs exactly, calculate the formal charge on every atom, and finish by checking that the formal charges add up to the overall charge of the species. A set of formal charges that fails that sum is wrong, however reasonable each value looked.

Do not look at the answer key until you have attempted every question. The key gives full working, so compare your method, not just your final answer.

Section A: Recall and Concepts

A1. Define resonance structures and the resonance hybrid of a species, and state the three things that must be identical in every resonance structure of that species.

A2. State the formula for formal charge in its full form, and in the shortcut form that counts dots and bonds. Then use it to calculate the formal charge on an atom that has 6 valence electrons, two bonding pairs and two lone pairs in the diagram.

A3. The ammonium ion, NH_4^+, has a correct Lewis diagram with four single bonds and no lone pairs. Explain why NH_4^+ has no resonance structures.

A4. A student writes that the carbonate ion "keeps flipping between its three structures, spending one third of its time in each". Correct the student's picture, and state the experimental observation about carbonate's bond lengths that the corrected picture explains.

A5. State, in order, the four tests used to judge which of several valid Lewis structures or resonance contributors is the most important, most stable one.

Section B: Core Practice

B1. The nitrate ion, NO_3^-, has nitrogen as its central atom. (a) Calculate the total valence electron count of the ion. (b) Describe one resonance contributor completely: the bond to each oxygen, the lone pairs on nitrogen, and the lone pairs on each kind of oxygen. (c) Calculate the formal charge on every atom in your contributor, and verify the sum. (d) State how many equivalent contributors NO_3^- has, and calculate the average N−O bond order in the hybrid.

B2. Ozone, O_3, consists of a central oxygen bonded to two terminal oxygens. (a) Calculate the total valence electron count of the molecule. (b) Describe one resonance contributor completely: both

© 2026 ExamFitter.com · Free AP Chemistry worksheets

bonds, and the lone pairs on each of the three oxygens. (c) Calculate the formal charge on each oxygen, and verify the sum. (d) Explain why the two contributors contribute equally, and state the average O−O bond order and what it predicts about the two O−O bond lengths.

B3. The formate ion, $HCOO^-$, has a carbon atom bonded to one hydrogen and to two oxygens. (a) Calculate the total valence electron count of the ion. (b) Describe one resonance contributor completely: all three bonds, and the lone pairs on each oxygen. (c) Calculate the formal charge on every atom, and verify the sum. (d) Calculate the average C−O bond order in the hybrid, and state what it predicts about the relative lengths of the two C−O bonds.

B4. The sulfate ion, SO_4^{2-}, has sulfur as its central atom. (a) Calculate the total valence electron count of the ion. (b) In the diagram with four single bonds, calculate the formal charge on sulfur and on each oxygen, and verify the sum. (c) In the diagram with two double bonds and two single bonds, calculate the formal charge on sulfur, on a double bonded oxygen, and on a single bonded oxygen, verify the sum, and state how many electrons surround sulfur. (d) State which diagram is preferred, and give the reason in terms of the judging tests.

B5. The cyanate ion, NCO^-, has the connectivity N−C−O and 16 valence electrons. Three valid contributors have these bond patterns: contributor A has a triple bond between N and C and a single bond between C and O; contributor B has double bonds throughout; contributor C has a single bond between N and C and a triple bond between C and O. In every contributor each atom has a complete octet. (a) For contributor A, state the lone pairs on each atom and calculate every formal charge. (b) For contributor B, state the lone pairs on each atom and calculate every formal charge. (c) State which contributor is dominant, and give the reason. (d) Contributor C places a formal charge of −2 on nitrogen and +1 on oxygen. State, without further calculation, why it contributes negligibly.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

B6. Boron trifluoride, BF_3, has 24 valence electrons. (a) Calculate the formal charge on every atom in the standard diagram: three single bonds, three lone pairs on each fluorine, and no lone pair on boron. (b) One fluorine lone pair is now converted into a second B−F bond. Calculate the new formal charges on boron and on that fluorine, and state how many electrons surround boron in this diagram. (c) State which diagram is the accepted structure of BF_3, and explain the apparent contradiction with the "complete the octets first" rule.

Section C: Exam Style

C1. Nitrous oxide, N_2O, is a neutral molecule with the connectivity N−N−O. (a) Calculate the total valence electron count of the molecule. (b) Contributor A joins the terminal nitrogen to the central nitrogen with a triple bond and the central nitrogen to oxygen with a single bond; every atom has an octet, the terminal nitrogen carries one lone pair and the oxygen carries three. Calculate the formal charge on each atom, and verify the sum. (c) Contributor B has two double bonds; the terminal nitrogen carries two lone pairs and the oxygen carries two. Calculate the formal charge on each atom, and verify the sum. (d) State which contributor is dominant, and justify the choice using the judging tests.

C2. The phosphate ion, PO_4^{3-}, has phosphorus as its central atom. (a) Calculate the total valence electron count of the ion. (b) In the diagram with four single bonds, calculate the formal charge on phosphorus and on each oxygen, and verify the sum. (c) In the diagram with one double bond and three single bonds, calculate every formal charge, verify the sum, and calculate the average P−O bond order in the hybrid built from this contributor pattern. (d) Explain why the best diagram of PO_4^{3-} contains exactly one double bond rather than two, given that a second double bond is geometrically possible for phosphorus.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

C3. The thiocyanate ion, SCN^-, has the connectivity S−C−N and 16 valence electrons. (a) Contributor A has double bonds between S and C and between C and N; sulfur carries two lone pairs and nitrogen carries two lone pairs. Calculate the formal charge on every atom, and verify the sum. (b) Contributor B has a single bond between S and C and a triple bond between C and N; sulfur carries three lone pairs and nitrogen carries one lone pair. Calculate the formal charge on every atom, and verify the sum. (c) State which contributor is dominant, and give the reason, naming the electronegativities involved. (d) A third contributor, with a triple bond between S and C and a single bond between C and N, gives sulfur a formal charge of +1 and nitrogen a formal charge of −2. State why it is a negligible contributor.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Answer Key

A1. Resonance structures (contributors) are the two or more valid Lewis diagrams of a single species that differ only in the placement of multiple bonds and lone pairs. The resonance hybrid is the real structure of the species: a single, static blend of the contributors, with the shared bonding delocalized over all the positions the contributors use. The three things identical in every contributor are the positions and connectivity of the atoms (which atoms are bonded to which), the total number of valence electrons, and the overall charge of the species. If any of those three changes, the drawing is a different species, not another contributor.

A2. Full form: formal charge = valence electrons − (nonbonding electrons + ½ × bonding electrons). Shortcut form: formal charge = valence electrons − dots − bonds, where dots are the atom's nonbonding electrons and bonds are the number of bond lines touching it. For the given atom: it has 6 valence electrons, two bonding pairs (so 2 bonds, 4 bonding electrons) and two lone pairs (4 nonbonding electrons). Formal charge = 6 − (4 + 2) = 0. The shortcut agrees: 6 − 4 dots − 2 bonds = 0.

A3. Resonance needs electrons that can be rearranged: a multiple bond that can change position, or a lone pair that can become a bond. NH_4^+ owns 5 + (4 × 1) − 1 = 8 valence electrons, all of them spent in its four N−H single bonds; nitrogen carries no lone pair and there is no multiple bond anywhere. Any attempted rearrangement would have to break a single bond or move a hydrogen atom, and either change produces a different species, not a resonance contributor. So ammonium has exactly one Lewis diagram and no resonance.

A4. The ion does not flip. The three contributors are drawings, and the real carbonate ion is one static resonance hybrid in which the double bond character and the negative charge are shared equally over all three C−O positions at all times. The observation this explains is that all three C−O bond lengths in carbonate are measured to be identical, and each length sits between that of a typical C−O single bond and a C=O double bond, matching the hybrid's average bond order of (2 + 1 + 1) / 3 = 4/3. A flipping ion would show one short and two long bonds at any instant.

A5. In order: (1) complete octets, above all on period 2 atoms, which can never exceed eight electrons; (2) minimize formal charges, preferring the diagram with the fewest and smallest charges; (3) minimize charge separation, the number of atoms carrying charges of opposite sign; (4) place any unavoidable negative formal charge on the most electronegative atom, and positive charge on a less electronegative atom. Applied out of order, the tests mislead: formal charge minimization never justifies breaking a period 2 octet, and octets are not completed by putting positive charge on fluorine.

B1. (a) Nitrogen contributes 5, the three oxygens contribute 3 × 6 = 18, and the 1− charge adds 1: 5 + 18 + 1 = 24 valence electrons. (b) Nitrogen is joined to one oxygen by a double bond and to

© 2026 ExamFitter.com · Free AP Chemistry worksheets

each of the other two oxygens by a single bond. Nitrogen carries no lone pair. The double bonded oxygen carries two lone pairs; each single bonded oxygen carries three lone pairs. (c) Nitrogen: 5 − (0 + 4) = +1, since it touches four bond lines and has no nonbonding electrons. Double bonded oxygen: 6 − (4 + 2) = 0. Each single bonded oxygen: 6 − (6 + 1) = −1. Sum: +1 + 0 − 1 − 1 = −1, the charge of the ion, and the placed electrons audit: 8 bonding + 16 lone pair electrons = 24. (d) Three equivalent contributors, one for each choice of double bonded oxygen. Average bond order: the contributors place bond orders 2, 1 and 1 across the three positions, so each N−O bond averages (2 + 1 + 1) / 3 = 4/3, about 1.33.

B2. (a) 3 × 6 = 18 valence electrons. (b) The central oxygen is joined to one terminal oxygen by a double bond and to the other by a single bond. The central oxygen carries one lone pair. The double bonded terminal oxygen carries two lone pairs; the single bonded terminal oxygen carries three lone pairs. (c) Central oxygen: 6 − (2 + 3) = +1 (one lone pair is 2 nonbonding electrons; three bond lines give it half of 6 bonding electrons, 3). Double bonded oxygen: 6 − (4 + 2) = 0. Single bonded oxygen: 6 − (6 + 1) = −1. Sum: +1 + 0 − 1 = 0, correct for a neutral molecule. Placed electrons: 6 bonding + 12 in lone pairs = 18. (d) The second contributor is the mirror image of the first, swapping which terminal oxygen is double bonded and which carries the −1 charge. Identical atoms in identical environments give the two contributors the same energy and the same formal charge pattern, so they contribute equally. Average bond order: (2 + 1) / 2 = 1.5 for each O−O bond, which predicts the two bonds are equal in length, each between a single and a double bond, as is observed.

B3. (a) Carbon contributes 4, hydrogen 1, the two oxygens contribute 2 × 6 = 12, and the 1− charge adds 1: 4 + 1 + 12 + 1 = 18 valence electrons. (b) Carbon is joined to hydrogen by a single bond, to one oxygen by a double bond, and to the other oxygen by a single bond. Carbon carries no lone pair, and neither does hydrogen. The double bonded oxygen carries two lone pairs; the single bonded oxygen carries three lone pairs. (c) Carbon: 4 − (0 + 4) = 0. Hydrogen: 1 − (0 + 1) = 0. Double bonded oxygen: 6 − (4 + 2) = 0. Single bonded oxygen: 6 − (6 + 1) = −1. Sum: 0 + 0 + 0 − 1 = −1, the charge of the ion. Placed electrons: 8 bonding + 10 in lone pairs = 18. (d) The two contributors swap the double bond between the two oxygens, so the C−O bond orders 2 and 1 are shared over two positions: average (2 + 1) / 2 = 1.5. Both C−O bonds are therefore the same length in the hybrid, intermediate between single and double, even though every individual contributor draws them differently.

B4. (a) Sulfur contributes 6, the four oxygens contribute 4 × 6 = 24, and the 2− charge adds 2: 6 + 24 + 2 = 32 valence electrons. (b) Sulfur touches four bond lines and has no lone pair: 6 − (0 + 4) = +2. Each oxygen has one bond and three lone pairs: 6 − (6 + 1) = −1. Sum: +2 + (4 × −1) = −2, the charge of the ion. (c) Sulfur now touches six bond lines (two double, two single) and still has no lone pair: 6 − (0 + 6) = 0. A double bonded oxygen: 6 − (4 + 2) = 0. A single bonded oxygen: 6 − (6 + 1) = −1. Sum: 0 + 0 + 0 − 1 − 1 = −2, verified. Sulfur is surrounded by 2 × 4 + 2 × 2 = 12 electrons, an expanded shell, legal because sulfur is in period 3. The placed electrons still total 32: 12

© 2026 ExamFitter.com · Free AP Chemistry worksheets

bonding + 20 in lone pairs. (d) The two-double-bond diagram is preferred. Both diagrams give every atom at least an octet, so the first test does not separate them, and the second test decides: the expanded diagram's charges (0, 0, 0, −1, −1) are far smaller than the all-single diagram's (+2 and four −1s), with less charge separation as well.

B5. (a) Contributor A: nitrogen carries one lone pair, carbon none, oxygen three lone pairs. Nitrogen: 5 − (2 + 3) = 0. Carbon: 4 − (0 + 4) = 0. Oxygen: 6 − (6 + 1) = −1. Sum: −1, the ion's charge. (b) Contributor B: nitrogen carries two lone pairs, carbon none, oxygen two lone pairs. Nitrogen: 5 − (4 + 2) = −1. Carbon: 4 − (0 + 4) = 0. Oxygen: 6 − (4 + 2) = 0. Sum: −1, verified. Both contributors place 16 electrons (8 bonding, 8 in lone pairs) and complete every octet. (c) Contributor A is dominant. The first three tests tie: both have complete octets, one formal charge each, and no charge separation beyond that single charge. The fourth test decides: the unavoidable −1 sits on oxygen in A and on nitrogen in B, and oxygen is the more electronegative atom, so A carries its charge more comfortably and contributes more to the hybrid. (d) A −2 formal charge is a large charge on one atom, and the contributor also places +1 on oxygen, the most electronegative atom in the ion, the worst home for a positive charge. Both faults put it far above A and B in energy, so it contributes negligibly.

B6. (a) Boron: 3 − (0 + 3) = 0. Each fluorine: 7 − (6 + 1) = 0. Every formal charge is zero, even though boron is surrounded by only 6 electrons. (b) Boron now touches four bond lines: 3 − (0 + 4) = −1. The double bonded fluorine has two bonds and two lone pairs: 7 − (4 + 2) = +1. The other two fluorines stay at 0. Boron is surrounded by 8 electrons, a complete octet. The placed electrons are unchanged at 24: 8 bonding + 16 in lone pairs. (c) The standard diagram, with the incomplete octet, is accepted. There is no true contradiction: the hierarchy puts octets first for period 2 atoms whose octet can be completed at a reasonable charge cost, but completing boron's octet here demands a positive formal charge on fluorine, the most electronegative element, and a negative charge on boron. That charge pattern is worse than a 6 electron boron with zero charges everywhere, so the octet test yields. Fluorine's own octet, note, is complete in both diagrams: only boron's count changes.

C1. (a) Two nitrogens and one oxygen, no charge: 5 + 5 + 6 = 16 valence electrons. (b) Terminal nitrogen: one lone pair and three bond lines, 5 − (2 + 3) = 0. Central nitrogen: no lone pair and four bond lines (triple plus single), 5 − (0 + 4) = +1. Oxygen: three lone pairs and one bond line, 6 − (6 + 1) = −1. Sum: 0 + 1 − 1 = 0, correct for a neutral molecule. Placed electrons: 8 bonding + 8 in lone pairs = 16. (c) Terminal nitrogen: two lone pairs and two bond lines, 5 − (4 + 2) = −1. Central nitrogen: four bond lines (two doubles), 5 − (0 + 4) = +1. Oxygen: two lone pairs and two bond lines, 6 − (4 + 2) = 0. Sum: −1 + 1 + 0 = 0, verified. (d) Contributor A is dominant. Both contributors complete every octet and carry the same total of formal charge (one +1, one −1), so the first tests tie. The deciding test is charge placement: A puts the −1 charge on oxygen, the most electronegative atom in the molecule, while B puts it on the terminal nitrogen and leaves oxygen neutral. A therefore lies lower in energy and contributes most.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

C2. (a) Phosphorus contributes 5, the four oxygens contribute 4 × 6 = 24, and the 3− charge adds 3: 5 + 24 + 3 = 32 valence electrons. (b) Phosphorus touches four bond lines and has no lone pair: 5 − (0 + 4) = +1. Each oxygen: 6 − (6 + 1) = −1. Sum: +1 + (4 × −1) = −3, the charge of the ion. (c) Phosphorus touches five bond lines: 5 − (0 + 5) = 0. The double bonded oxygen: 6 − (4 + 2) = 0. Each single bonded oxygen: 6 − (6 + 1) = −1. Sum: 0 + 0 + (3 × −1) = −3, verified. Average P−O bond order: the pattern places bond orders 2, 1, 1, 1 over the four equivalent positions, and the hybrid averages (2 + 1 + 1 + 1) / 4 = 5/4 = 1.25. (d) One double bond is exactly enough to bring phosphorus from +1 to 0, leaving the ion's three unavoidable −1 charges on three oxygens, where negative charge is comfortable. A second double bond would push phosphorus to 5 − (0 + 6) = −1: it would not reduce the number of charged atoms (still one charge on phosphorus plus two on oxygens), it would add charge separation, and it would park a negative charge on phosphorus, a less electronegative atom than oxygen. Every test after the first therefore penalizes the second double bond, so the best diagram stops at one. (Phosphorus, in period 3, is surrounded by 10 electrons in this diagram; the limit is set by formal charge, not by any octet ceiling.)

C3. (a) Sulfur: two bonds and two lone pairs, 6 − (4 + 2) = 0. Carbon: four bond lines and no lone pair, 4 − (0 + 4) = 0. Nitrogen: two bonds and two lone pairs, 5 − (4 + 2) = −1. Sum: 0 + 0 − 1 = −1, the charge of the ion. Placed electrons: 8 bonding + 8 in lone pairs = 16. (b) Sulfur: one bond and three lone pairs, 6 − (6 + 1) = −1. Carbon: 4 − (0 + 4) = 0. Nitrogen: three bonds and one lone pair, 5 − (2 + 3) = 0. Sum: −1 + 0 + 0 = −1, verified. Placed electrons: 8 bonding + 8 in lone pairs = 16. (c) Contributor A is dominant. Both contributors have complete octets and exactly one formal charge, so the decision falls to charge placement: in A the −1 charge sits on nitrogen, while in B it sits on sulfur. Nitrogen is more electronegative than sulfur (nitrogen is a period 2 nonmetal well to the right of its period; sulfur sits below oxygen in group 16), so the charge is held more comfortably on nitrogen and A contributes most to the hybrid. (d) That contributor carries two faults at once: a +1 charge on sulfur and a −2 charge, a large charge on a single atom, on nitrogen. Its total charge magnitude and separation far exceed those of A and B, so it lies much higher in energy and contributes negligibly.

Continue Revising

Topic 2.6 Revision Notes

Topic 2.6 Quiz: Resonance and Formal Charge

Previous Worksheet: Topic 2.5 Lewis Diagrams

Next Worksheet: Topic 2.7 VSEPR and Hybridization

© 2026 ExamFitter.com · Free AP Chemistry worksheets