AP CHEMISTRY

UNIT 2 PRACTICE TEST

TEST FORM 5

COMPOUND STRUCTURE AND PROPERTIES

60 Multiple-Choice Questions • Seven Free-Response Questions

Calculator Permitted

General Test Instructions

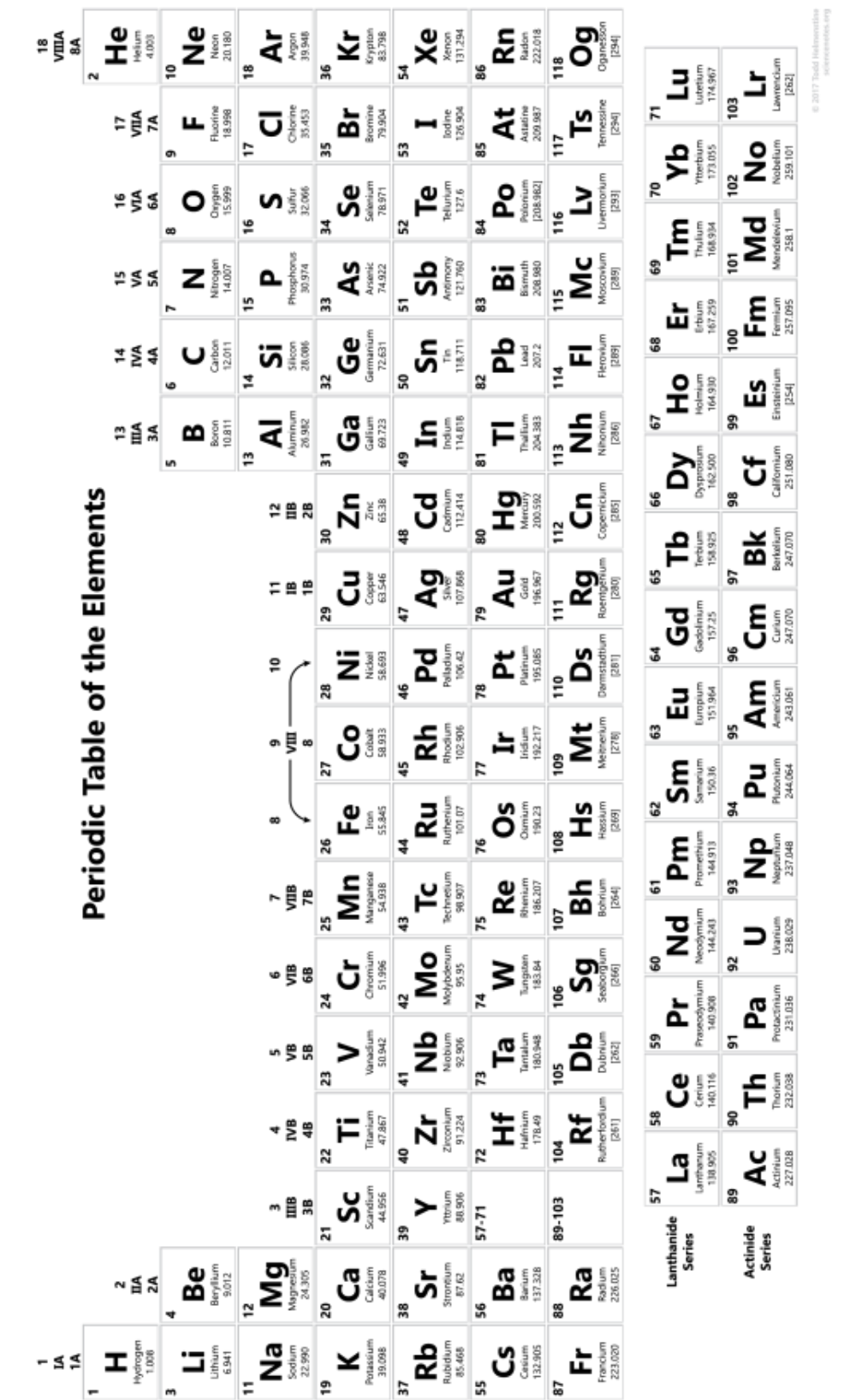
This examination contains only AP Chemistry Unit 2 content. It is designed as a full-length, high-volume unit assessment rather than a content-balanced simulation of the complete AP Chemistry course.

Section I: 60 multiple-choice questions; 90 minutes; choose one answer (A–D) for each question. There is no penalty for an incorrect answer.

Section II: seven free-response questions; 105 minutes; Questions 1–3 are long (10 points each) and Questions 4–7 are short (4 points each). Total: 46 points.

A calculator is permitted throughout this practice test. Show formulas, substitutions, units, significant figures, and chemically specific reasoning in the free-response section. Student pages contain no answers or scoring commentary. Remove the teacher section before assigning the test.

Periodic Table



Section I: Multiple-Choice Questions

60 Questions · 90 Minutes · 60 Points

Directions: Select the best answer for each question. Use the answer grid after Question 60.

1. In a comparison involving silicon, Si and the Si—F bond, consider an isolated Si—F covalent bond with χ values 1.9 and 4.0. Which diagram best represents its electron-density shift?

(A) $Si\delta^{+}$—$F\delta^{-}$
(B) $Si\delta^{-}$—$F\delta^{+}$
(C) Si—F with equal sharing
(D) $Si^{+}F^{-}$ with complete transfer

2. While a class relates Si/F electronegativity to bulk solid behavior, a material made from one element can be drawn into wire and has mobile charge carriers in two phases. Which structure is most consistent?

(A) A rigid network of localized two-center bonds
(B) Neutral molecules held by dispersion forces
(C) Positive metal cores attracted to delocalized valence electrons
(D) Alternating cations and anions with fixed electrons

3. During a particle-level review that contrasts silicon, Si with ionic and metallic samples, to melt silicon, Si, many strong directional bonds throughout the crystal must be disrupted. Which type of solid is it?

(A) Metallic solid
(B) Network-covalent solid
(C) Ionic solid made of monatomic ions
(D) Molecular solid

4. In a comparison involving silicon, Si and the Si—F bond, which two elements most naturally form a cation–anion lattice rather than discrete covalent molecules?

(A) Mg and P
(B) S and Cl
(C) C and N
(D) B and H

5. While a class relates Si/F electronegativity to bulk solid behavior, what new feature appears in Si—F that is absent from homonuclear F—F?

(A) The heteronuclear bond has a bond dipole, whereas the homonuclear bond does not
(B) Both bonds have identical electron-density distributions
(C) The heteronuclear bond must be fully ionic
(D) Only the homonuclear bond shares electrons

6. During a particle-level review that contrasts silicon, Si with ionic and metallic samples, a crystalline material carries current only when its particles become mobile and shatters under stress. What is it most likely?

(A) Network covalent with no ions
(B) Metallic
(C) Ionic
(D) Molecular covalent

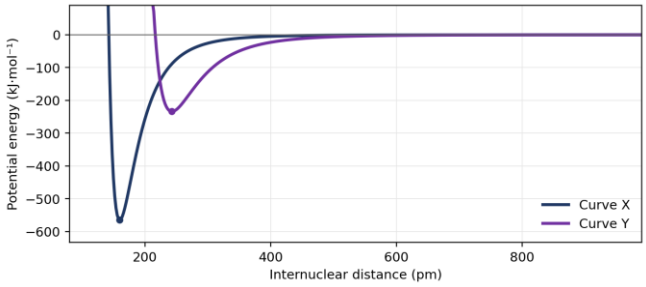
7. In a comparison involving silicon, Si and the Si—F bond, a calculated charge distribution gives F a small negative partial charge in SiF. How should the bond be described?

(A) The bond is polar covalent
(B) The electron pair has been transferred completely
(C) The bond is nonpolar covalent
(D) The atoms have formed a metallic bond

8. While a class relates Si/F electronegativity to bulk solid behavior, which behavior would be expected for a solid composed of intact neutral molecules?

(A) High melting point and conduction when molten
(B) High conductivity as a solid
(C) A low melting point and no electrical conductivity in either phase
(D) Extreme hardness from an extended bond network

Questions 9–12 refer to the potential-energy curves. Separated atoms are assigned zero potential energy.



9. Using this form's Si—F/Si—I potential-energy investigation as context, curve X has its minimum near 160 pm and −565 kJ·mol⁻¹; Curve Y has its minimum near 243 pm and −234 kJ·mol⁻¹. Which assignment is consistent with the supplied bond data?

(A) The curves cannot represent bonded atoms because their minima are negative
(B) X is Si—F and Y is Si—I
(C) X is Si—I and Y is Si—F
(D) Both curves describe the stronger bond

10. While interpreting energy and force for Si—F and Si—I, which statement applies at the stable separation marked by the bottom of Curve X?

(A) Only repulsion remains
(B) Attractive and repulsive contributions balance, so the net force is zero
(C) Only attraction remains
(D) The atoms are infinitely separated

Questions 11–12 continue to refer to the potential-energy curves on the preceding page.

11. In a model calibrated to the 160 pm and 243 pm equilibrium separations, what is the approximate energy change when one mole of Si—I bonds forms from separated gaseous atoms?

(A) +243 kJ·mol⁻¹
(B) +234 kJ·mol⁻¹
(C) −243 kJ·mol⁻¹
(D) −234 kJ·mol⁻¹

12. Using this form's Si—F/Si—I potential-energy investigation as context, approximately how much energy must be supplied to dissociate one mole of Si—F bonds into separated gaseous atoms?
(A) −565 kJ
(B) 160 kJ
(C) 565 kJ
(D) 234 kJ

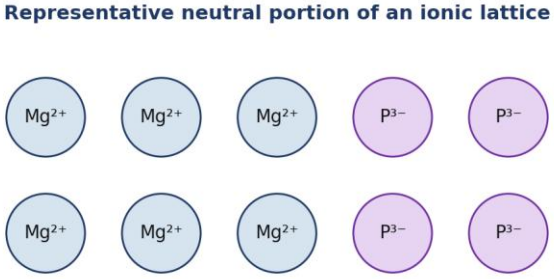
13. While interpreting energy and force for Si—F and Si—I, the equilibrium lengths of Si—F and Si—I are 160 pm and 243 pm. Which statement is supported?
(A) Both bonds must have the same equilibrium length
(B) Si—I is shorter because its energy is less negative
(C) Si—F reaches its energy minimum at the smaller separation
(D) Bond length is unrelated to the location of a potential-energy minimum

14. In a model calibrated to the 160 pm and 243 pm equilibrium separations, a vibrational displacement moves the atoms substantially closer than the energy minimum. Which microscopic effect dominates?
(A) It decreases without limit as the nuclei approach
(B) It approaches zero from below because all interactions vanish
(C) It remains at the minimum
(D) It rises steeply because nucleus–nucleus and electron-cloud repulsions dominate

15. Using this form's Si—F/Si—I potential-energy investigation as context, a photon supplies 224 $kJ \cdot mol^{-1}$ to molecules at the minimum of the Si—I curve. Which conclusion is most defensible?
(A) Every bond must dissociate because any positive energy breaks a bond
(B) The atoms reach a potential energy below the minimum
(C) The bond becomes shorter by exactly 10 pm
(D) The supplied energy is slightly below the stated dissociation energy, so complete dissociation is not guaranteed

16. While interpreting energy and force for Si—F and Si—I, how is increased bond strength encoded on a potential-energy diagram whose asymptote remains at zero?
(A) The minimum becomes deeper below zero
(B) The curve loses its repulsive wall
(C) The minimum moves above zero
(D) The entire zero-energy line moves downward

Questions 17–19 refer to the representative ionic-lattice portion below.



17. Within a structure–property investigation of Mg_3P_2, a particle diagram contains 6 Mg^{2+} ions and 4 P^{3-} ions. What empirical formula is represented?
(A) Mg_3P_2
(B) $Mg^{2+}P^{3-}$
(C) AB_3
(D) A_2B

18. Using Mg_3P_2 as the reference ionic lattice, which statement verifies electrical neutrality for the Mg_3P_2 particle model?
(A) The numbers of cations and anions must be equal
(B) Only the cations contribute to the total charge
(C) The total positive and negative charges have equal magnitude
(D) Every ion has zero formal charge

19. While comparing the Mg^{2+}/P^{3-} lattice with other salts, why can molten Mg_3P_2 conduct electricity although solid Mg_3P_2 cannot?
(A) Covalent bonds form only in the liquid
(B) Electrons become shared equally between every neighboring ion
(C) Melting frees the ions to translate through the sample
(D) Melting changes the ions into neutral atoms

20. Within a structure–property investigation of Mg_3P_2, using charge magnitude and ion size, which solid is predicted to have the greatest lattice-energy magnitude?
(A) KCl
(B) BeO
(C) NaF
(D) RbBr

21. Using Mg_3P_2 as the reference ionic lattice, for salts that differ only in ion size, identify the sample expected to have the stronger lattice binding.
(A) Replacing both ions with larger ions
(B) Changing the solid into neutral molecules
(C) Replacing the ions with smaller ions
(D) Removing all charged particles

22. While comparing the Mg^{2+}/P^{3-} lattice with other salts, why does forced layer motion destabilize an ordered cation–anion array rather than produce metallic-style deformation?
(A) The ions lose all charge under stress
(B) A shifted layer can place like charges adjacent, producing strong repulsion
(C) Discrete molecules rotate freely into new positions
(D) Mobile electrons lubricate the lattice

23. Within a structure–property investigation of Mg_3P_2, as an ionic lattice loses long-range order on heating, what happens to the motion of its charged particles?
(A) Valence electrons become a metallic electron sea
(B) Enough ion–ion attractions are disrupted for ions to move past one another
(C) Every polyatomic ion must decompose
(D) All ions are converted to gaseous neutral atoms

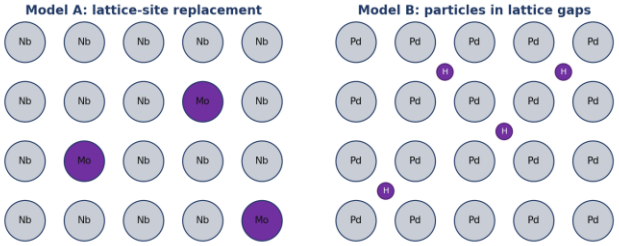
24. Using Mg_3P_2 as the reference ionic lattice, the formula units of a soluble salt separate in water. What subsequently moves under an applied electric field?

(A) Hydrated cations and anions moving in opposite directions
(B) Only water molecules
(C) Stationary formula units
(D) Shared electron pairs moving through covalent bonds

25. While comparing the Mg^{2+}/P^{3-} lattice with other salts, a crystal of Mg_3P_2 contains a vacancy where one Mg^{2+} ion is missing. Which additional change could restore charge neutrality locally?

(A) Remove ions whose total negative charge matches the missing positive charge
(B) Add another anion of any charge
(C) Remove another cation only
(D) Convert every ion to a neutral molecule

Questions 26–28 refer to the two metal-alloy particle models.



26. While comparing the Nb–Mo and Pd–H alloy models, in Model A, some Nb atoms (146 pm) are replaced at normal lattice sites by Mo atoms (139 pm). How is the alloy classified?

(A) Interstitial alloy
(B) Molecular solid
(C) Substitutional alloy
(D) Ionic solid

27. During analysis of metallic bonding in a Nb-rich solid solution, model B places small H atoms (37 pm) in holes between Pd atoms (137 pm). Which label is correct?

(A) Pure metal
(B) Substitutional alloy
(C) Network-covalent solid
(D) Interstitial alloy

28. Using the Pd host lattice and its small H guest atoms as a reference, a stress–strain test shows that the alloy requires greater applied stress than the pure metal. What microscopic feature is responsible?

(A) Every atom becomes an anion
(B) All metallic attractions are replaced by hydrogen bonds
(C) Guest atoms distort the regular lattice and hinder layer or dislocation motion
(D) The alloy contains no valence electrons

29. While comparing the Nb–Mo and Pd–H alloy models, what moves through the extended metal lattice when a potential difference is applied?

(A) Neutral atoms flowing through vacancies
(B) Metal cations migrating through the lattice
(C) Localized bonding pairs confined between two nuclei
(D) Delocalized valence electrons

30. During analysis of metallic bonding in a Nb-rich solid solution, which nondirectional attraction explains plastic deformation without immediate fracture in a metal?

(A) Metallic bonding is nondirectional, so shifted cores remain attracted to the electron sea
(B) Every metal contains alternating anions
(C) Metal atoms are separate molecules
(D) Bending creates new ionic charges that glue the sample together

31. Using the Pd host lattice and its small H guest atoms as a reference, the atomic radii of Nb and Mo differ by only 7 pm. Which particle sketch would best represent a homogeneous Nb–Mo alloy?

(A) Large host atoms with tiny guest atoms only in gaps
(B) A regular lattice with a subset of similarly sized sites labeled as the guest metal
(C) Separate clusters of discrete diatomic molecules
(D) Alternating positive and negative ions

32. While comparing the Nb–Mo and Pd–H alloy models, which observation would distinguish the Pd–H alloy from an ionic crystal?

(A) It has particles in a repeating arrangement
(B) It conducts as a solid because delocalized electrons remain mobile
(C) It contains two elements
(D) It can be represented by circles

33. During analysis of metallic bonding in a Nb-rich solid solution, conductivity measurements are similar, but the alloy requires more stress to shape. What conclusion about lattice regularity follows?

(A) The guest atoms remove every bonding interaction
(B) The alloy has become a molecular liquid
(C) Lattice distortions impede the coordinated sliding of atomic planes
(D) The host atoms change into nonmetals

34. While validating a Lewis-diagram procedure with Br_2O, how many valence electrons must be included in a complete Lewis diagram for Br_2O?

(A) 24
(B) 18
(C) 22
(D) 20

35. In an electron-bookkeeping exercise that begins with Br_2O, in the lowest-formal-charge Lewis diagram with connectivity Br—O—Br, how many lone pairs appear in total?

(A) 8
(B) 9
(C) 6
(D) 10

36. During a comparison of octet completion and exceptions related to XeF_4, which statement describes the usual Lewis diagram for XeF_4?

(A) The central atom has no bonds and four lone pairs
(B) Every atom must have exactly eight electrons and no exceptions are possible
(C) The substance is represented only as separated monatomic ions
(D) Xe has four bonds and two lone pairs, exceeding an octet

37. While validating a Lewis-diagram procedure with Br_2O, to begin a Lewis construction reliably, what total must be obtained from atom counts and overall charge?

(A) Place all electrons on the least electronegative atom
(B) Ignore the charge until after the diagram is complete
(C) Count all valence electrons and adjust for the ion charge
(D) Assume every bond is double

38. In an electron-bookkeeping exercise that begins with Br_2O, what feature of the 1s valence shell makes a two-coordinate H center unacceptable in an ordinary Lewis diagram?

(A) Hydrogen can form only one bond because its valence shell holds two electrons
(B) Hydrogen has available d orbitals
(C) Hydrogen is always negatively charged
(D) Hydrogen must have four lone pairs

39. During a comparison of octet completion and exceptions related to XeF_4, determine the valence-shell electron count represented by three bond lines and one lone-pair symbol around one atom.

(A) 10
(B) 6
(C) 8
(D) 4

40. While validating a Lewis-diagram procedure with Br_2O, to complete a central octet, a nonbonding pair on an adjacent atom may be converted into what feature?

(A) Break every existing bond
(B) Add two electrons from nowhere
(C) Delete a terminal atom's valence electrons
(D) Convert a neighboring lone pair into an additional bonding pair

41. In an electron-bookkeeping exercise that begins with Br_2O, which orbital-capacity limitation is violated by placing more than eight electrons around a period-2 atom?

(A) The atom must be a metal
(B) The diagram is invalid because a second-period atom cannot expand its octet
(C) The electron count proves the molecule is ionic
(D) The diagram is automatically the only valid contributor

42. During a comparison of octet completion and exceptions related to XeF_4, at the end of the first octet-completion pass, which location is checked for the leftover nonbonding pairs?

(A) As positive formal charges
(B) On the central atom as lone pairs
(C) Only on hydrogen atoms
(D) Outside the molecule without an atom

43. During analysis of electron delocalization in IO_3^-, equivalent resonance contributors for IO_3^- distribute a total bond order of 5 across 3 equivalent bonds. What is the average bond order?

(A) 1
(B) 3/2
(C) 4/3
(D) 1.67

44. Using the resonance contributors of IO_3^- as a reference, why can IO_3^- require more than one Lewis contributor even though the atoms do not change positions?

(A) The ion alternates between ionic and metallic bonding
(B) Different valid placements of π electrons and formal charges describe one delocalized structure
(C) The nuclei rapidly exchange identities
(D) Each contributor is a different compound

45. While checking formal-charge and bond-order claims for IO_3^-, which expression assigns every lone-pair electron and one-half of every bonding pair to the atom under review?

(A) nonbonding electrons − valence electrons
(B) ½(valence electrons + bonding electrons)
(C) valence electrons + all bonding electrons
(D) valence electrons − nonbonding electrons − ½(bonding electrons)

46. During analysis of electron delocalization in IO_3^-, among octet-satisfying structures, identify the feature associated with a major resonance contributor.

(A) The one with smaller formal-charge magnitudes and less charge separation
(B) The one that changes atom connectivity
(C) The one with the most adjacent like charges
(D) The one with fewer total valence electrons

47. Using the resonance contributors of IO_3^- as a reference, if the 3 bonds around I in IO_3^- are experimentally equal, what does that observation support?

(A) Permanent localization of one unique multiple bond
(B) Rapid movement of the nuclei
(C) Complete electron transfer between identical atoms
(D) A resonance hybrid with delocalized bonding

48. While checking formal-charge and bond-order claims for IO_3^-, what invariant connects local formal-charge assignments with the net charge written on the species?

(A) The overall charge of the species
(B) Zero for every ion
(C) The number of lone pairs
(D) The number of bonds

49. During analysis of electron delocalization in IO_3^-, two valid drawings have equal charge separation but different negative-charge locations. Which atom should preferentially bear it?

(A) On H
(B) Formal-charge location never matters
(C) On the less electronegative atom
(D) On O, the more electronegative atom

50. Using the resonance contributors of IO_3^- as a reference, what remains constant when a double-headed resonance arrow connects two Lewis drawings?
(A) They mean the molecule is vibrating
(B) They connect electron-bookkeeping contributors for the same species, not reactants and products
(C) They show electron transfer to a metal
(D) They indicate an equilibrium between isolable compounds

51. While checking formal-charge and bond-order claims for IO_3^-, the 3 principal contributors of IO_3^- are equivalent. What follows about their importance?
(A) The contributor with bonds drawn horizontally dominates
(B) Their atom connectivities must differ
(C) Only the first drawn contributor is real
(D) They contribute equally to the resonance hybrid

52. While comparing the VSEPR models of N_2O and CO_3^{2-}, the central atom in N_2O has 2 bonding domains and 0 lone pairs. What is its molecular geometry?
(A) tetrahedral
(B) bent
(C) trigonal pyramidal
(D) linear

53. During a geometry-and-polarity study that includes H_2S, what hybridization is assigned to the central atom in CO_3^{2-} in the AP VSEPR model?
(A) sp^2
(B) sp^3d
(C) sp^3
(D) sp

54. Using the electron-domain counts of BrF_3 and SF_5^- as reference cases, which description of H_2S is correct?
(A) It is octahedral and nonpolar
(B) It is bent and polar
(C) It has no covalent bonds
(D) It is linear and nonpolar

55. While comparing the VSEPR models of N_2O and CO_3^{2-}, the central atom in BrF_3 has 3 bonded atoms and 2 lone pairs. Which geometry is predicted?
(A) T-shaped
(B) linear
(C) square planar
(D) tetrahedral

56. During a geometry-and-polarity study that includes H_2S, why is SF_5^- classified as polar?
(A) It contains no polar bonds
(B) All molecules with lone pairs are nonpolar
(C) Its bond-dipole vectors do not cancel in its asymmetric molecular geometry
(D) Hybridization alone removes every bond dipole

57. Using the electron-domain counts of BrF_3 and SF_5^- as reference cases, which interaction appears first in the standard ordering LP–LP, LP–BP, and BP–BP?
(A) core electron–core electron only
(B) lone pair–lone pair
(C) bond pair–nucleus
(D) bond pair–bond pair

58. While comparing the VSEPR models of N_2O and CO_3^{2-}, how many bonds of each symmetry type are created by H—C and the three components of C≡N?
(A) 4 σ and 0 π
(B) 3 σ and 1 π
(C) 2 σ and 2 π
(D) 1 σ and 3 π

59. During a geometry-and-polarity study that includes H_2S, an sp^3 center contains one lone pair rather than a fourth bonded atom. Which two geometry labels apply?
(A) octahedral; square planar
(B) linear; bent
(C) trigonal planar; tetrahedral
(D) tetrahedral electron-domain geometry; trigonal-pyramidal molecular geometry

60. Using the electron-domain counts of BrF_3 and SF_5^- as reference cases, tetrahedral electron-domain arrangements can produce different molecular shapes. What are the outcomes for two versus zero lone pairs?
(A) Both are tetrahedral
(B) The first is bent; the second is tetrahedral
(C) The first is linear; the second is bent
(D) The first is square planar; the second is trigonal planar

Section I Answer Grid

Record exactly one response for each question.

Q	Response	Q	Response	Q	Response
1	◯ A ◯ B ◯ C ◯ D	21	◯ A ◯ B ◯ C ◯ D	41	◯ A ◯ B ◯ C ◯ D
2	◯ A ◯ B ◯ C ◯ D	22	◯ A ◯ B ◯ C ◯ D	42	◯ A ◯ B ◯ C ◯ D
3	◯ A ◯ B ◯ C ◯ D	23	◯ A ◯ B ◯ C ◯ D	43	◯ A ◯ B ◯ C ◯ D
4	◯ A ◯ B ◯ C ◯ D	24	◯ A ◯ B ◯ C ◯ D	44	◯ A ◯ B ◯ C ◯ D
5	◯ A ◯ B ◯ C ◯ D	25	◯ A ◯ B ◯ C ◯ D	45	◯ A ◯ B ◯ C ◯ D
6	◯ A ◯ B ◯ C ◯ D	26	◯ A ◯ B ◯ C ◯ D	46	◯ A ◯ B ◯ C ◯ D
7	◯ A ◯ B ◯ C ◯ D	27	◯ A ◯ B ◯ C ◯ D	47	◯ A ◯ B ◯ C ◯ D
8	◯ A ◯ B ◯ C ◯ D	28	◯ A ◯ B ◯ C ◯ D	48	◯ A ◯ B ◯ C ◯ D
9	◯ A ◯ B ◯ C ◯ D	29	◯ A ◯ B ◯ C ◯ D	49	◯ A ◯ B ◯ C ◯ D
10	◯ A ◯ B ◯ C ◯ D	30	◯ A ◯ B ◯ C ◯ D	50	◯ A ◯ B ◯ C ◯ D
11	◯ A ◯ B ◯ C ◯ D	31	◯ A ◯ B ◯ C ◯ D	51	◯ A ◯ B ◯ C ◯ D
12	◯ A ◯ B ◯ C ◯ D	32	◯ A ◯ B ◯ C ◯ D	52	◯ A ◯ B ◯ C ◯ D
13	◯ A ◯ B ◯ C ◯ D	33	◯ A ◯ B ◯ C ◯ D	53	◯ A ◯ B ◯ C ◯ D
14	◯ A ◯ B ◯ C ◯ D	34	◯ A ◯ B ◯ C ◯ D	54	◯ A ◯ B ◯ C ◯ D
15	◯ A ◯ B ◯ C ◯ D	35	◯ A ◯ B ◯ C ◯ D	55	◯ A ◯ B ◯ C ◯ D
16	◯ A ◯ B ◯ C ◯ D	36	◯ A ◯ B ◯ C ◯ D	56	◯ A ◯ B ◯ C ◯ D
17	◯ A ◯ B ◯ C ◯ D	37	◯ A ◯ B ◯ C ◯ D	57	◯ A ◯ B ◯ C ◯ D
18	◯ A ◯ B ◯ C ◯ D	38	◯ A ◯ B ◯ C ◯ D	58	◯ A ◯ B ◯ C ◯ D
19	◯ A ◯ B ◯ C ◯ D	39	◯ A ◯ B ◯ C ◯ D	59	◯ A ◯ B ◯ C ◯ D
20	◯ A ◯ B ◯ C ◯ D	40	◯ A ◯ B ◯ C ◯ D	60	◯ A ◯ B ◯ C ◯ D

Section II: Free-Response Questions

7 Questions · 105 Minutes · 46 Points

Directions: Show reasoning, draw complete structures, label formal charges, and use supplied evidence. Unsupported answers may not receive full credit.

Question 1 (Long, 10 points)

Bromate Ion: Lewis Structure, Resonance, and Ionic Bonding

A salt contains the bromate ion, BrO_3^-. In a crystal, all Br—O bond lengths are experimentally equal at 165 pm. Typical localized single- and double-bond lengths are 175 pm and 156 pm, respectively.

(a) Determine the total number of valence electrons in BrO_3^-.

(b) Draw one lowest-formal-charge Lewis contributor. Show all lone pairs and formal charges.

(c) State the number of equivalent lowest-formal-charge contributors.

Question 1 continued

(d) Calculate the average Br—O bond order in the resonance hybrid.

(e) Use the measured bond lengths to explain why a single localized contributor is incomplete.

(f) State the molecular geometry and AP hybridization of the central atom. Justify using electron domains.

(g) Predict whether $Ba(BrO_3)_2$ or $NaBrO_3$ has the greater lattice-energy magnitude. Justify using charge and size.

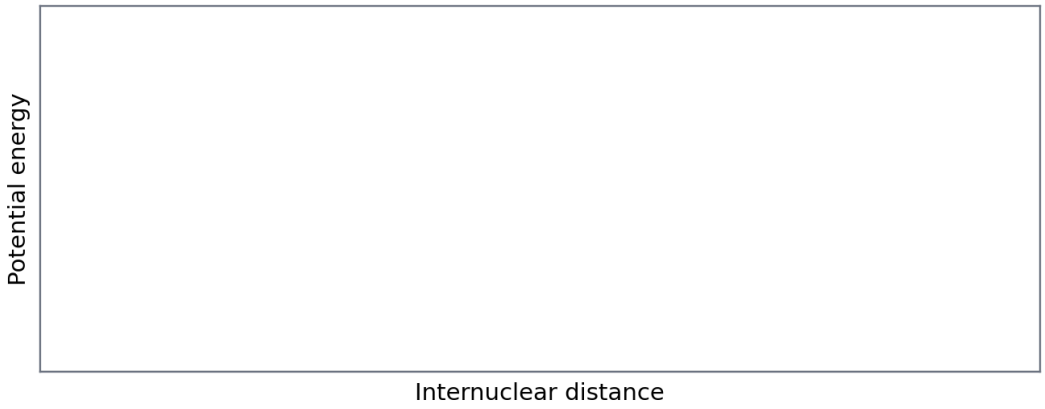
Question 2 (Long, 10 points)

Potential-Energy Investigation: B—F and B—Cl

Selected average bond data are: B—F, 130 pm and 613 kJ·mol⁻¹; B—Cl, 175 pm and 456 kJ·mol⁻¹. The potential energy of separated gaseous atoms is defined as zero.

(a) Identify the stronger bond and justify with the data.

(b) On common axes, sketch and label both potential-energy curves, placing each minimum at a consistent relative distance and depth.



(c) Calculate the energy change when one mole of B—Cl bonds forms from separated atoms.

Question 2 continued

(d) State the energy required to dissociate 0.250 mol of B—F bonds.

(e) Describe the net force at a curve minimum and explain using the slope of the curve.

(f) Explain why the shorter bond generally has the deeper minimum in this data set.

Question 3 (Long, 10 points)

Platinum–Carbon Alloy: Particle Model and Properties

The atomic radii are approximately 139 pm for Pt and 70 pm for C. In a homogeneous platinum–carbon sample, the guest atoms occupy spaces between the host-metal lattice sites.

(a) Classify the alloy as substitutional or interstitial.

(b) Justify the classification using the radius data and stated positions.

(c) Describe a particle-level drawing that distinguishes the alloy from the pure host metal.

Question 3 continued

(d) Explain why the alloy conducts electricity in the solid state.

(e) Predict how the guest atoms affect hardness relative to the pure host metal. Justify.

(f) Use the metallic-bonding model to explain why the sample can still be shaped without every bond breaking at once.

Question 4 (Short, 4 points)

Lewis Structure and VSEPR of SF_5^-

Consider the molecular species SF_5^-.

(a) Determine the total number of valence electrons and draw a complete lowest-formal-charge Lewis diagram.

(b) State the molecular geometry and AP hybridization of the central atom.

(c) Predict whether the species has a molecular dipole and justify using geometry.

Question 5 (Short, 4 points)

Ionic Lattice Attractions and Conductivity

A student compares crystalline Mg_3N_2 and K_2S.

(a) Predict which solid has the greater lattice-energy magnitude and justify.

(b) Explain why solid Mg_3N_2 does not conduct but molten Mg_3N_2 does.

Question 6 (Short, 4 points)

Resonance in Hydrogen Carbonate, HCO_3^-

Consider the resonance description of hydrogen carbonate, HCO_3^-.

(a) Draw or describe the principal resonance contributors, including formal charges.

(b) State the appropriate average bond order for the delocalized bond positions.

(c) Explain what equal intermediate bond lengths would show experimentally.

Question 7 (Short, 4 points)

Bonding and Properties of Boron Carbide, B_4C

A sample of boron carbide, B_4C is examined at the particle level.

(a) Classify the dominant bonding/solid type.

(b) Relate the bonding model to one mechanical or thermal property.

(c) Predict its electrical behavior and justify at the particle level.

TEACHER MATERIALS — DO NOT DISTRIBUTE WITH STUDENT EXAMINATION

Answer Key and Complete Solutions

Section I Answer Key

1. A	2. C	3. B	4. A	5. A	6. C	7. A	8. C	9. B	10. B
11. D	12. C	13. C	14. D	15. D	16. A	17. A	18. C	19. C	20. B
21. C	22. B	23. B	24. A	25. A	26. C	27. D	28. C	29. D	30. A
31. B	32. B	33. C	34. D	35. A	36. D	37. C	38. A	39. C	40. D
41. B	42. B	43. D	44. B	45. D	46. A	47. D	48. A	49. D	50. B
51. D	52. D	53. A	54. B	55. A	56. C	57. B	58. C	59. D	60. B

Answer-position balance: A = 15, B = 15, C = 15, D = 15.

Multiple-Choice Explanations

1. A — 2.1 Types of Chemical Bonds
F is more electronegative, so the shared electron density is displaced toward F. The bond is polar covalent, with δ^+ on Si and δ^- on F.

2. C — 2.1 Types of Chemical Bonds
Metallic bonding contains mobile, delocalized valence electrons. The attraction between those electrons and metal cores is nondirectional, explaining conductivity and ductility.

3. B — 2.1 Types of Chemical Bonds
The stated behavior follows from a three-dimensional lattice of directional Si—Si bonds. Such an extended covalent network has no discrete molecules and requires many strong bonds to be disrupted.

4. A — 2.1 Types of Chemical Bonds
Mg and P combines a metal that readily forms a cation with a nonmetal that readily forms an anion. The alternatives contain only nonmetals and favor covalent bonding.

5. A — 2.1 Types of Chemical Bonds
The different electronegativities of Si and F make Si—F polar. Identical atoms in F—F share electrons equally, so no bond dipole results.

6. C — 2.1 Types of Chemical Bonds
An ionic lattice contains fixed ions in the solid and mobile ions when molten. Shifting lattice planes can align like charges, causing brittle fracture.

7. A — 2.1 Types of Chemical Bonds
A shifted but still shared bonding pair is the defining feature of a polar covalent bond.

8. C — 2.1 Types of Chemical Bonds
Molecular substances consist of neutral molecules. They lack mobile ions or delocalized electrons and often melt at relatively low temperatures because only intermolecular attractions are overcome.

Multiple-Choice Explanations (continued)

9. B — 2.2 Intramolecular Force and Potential Energy
Si—F has the shorter bond length and larger dissociation energy, so it must have the shorter, deeper minimum (Curve X).

10. B — 2.2 Intramolecular Force and Potential Energy
At a potential-energy minimum, the slope dE/dr is zero. Since force is −dE/dr, the net force is zero even though attractive and repulsive interactions are both present.

11. D — 2.2 Intramolecular Force and Potential Energy
The separated-atom limit is defined as zero. Moving to the Curve Y minimum releases 234 kJ per mole, so $\Delta E = -234$ kJ·mol^{-1}.

12. C — 2.2 Intramolecular Force and Potential Energy
Dissociation moves the system from the −565 kJ·mol^{-1} minimum to zero, requiring +565 kJ for one mole.

13. C — 2.2 Intramolecular Force and Potential Energy
The x-coordinate of a potential-energy minimum is the equilibrium bond length. The smaller listed length therefore belongs farther left on the graph.

14. D — 2.2 Intramolecular Force and Potential Energy
At very short separations, repulsive interactions increase sharply, producing the steep left side of a bond potential-energy curve.

15. D — 2.2 Intramolecular Force and Potential Energy
The listed dissociation energy is about 234 kJ·mol^{-1}. An input of 224 kJ·mol^{-1} is below that threshold for molecules starting at the minimum.

16. A — 2.2 Intramolecular Force and Potential Energy
A stronger bond requires more energy to dissociate. With separated atoms fixed at zero, that corresponds to a minimum of greater negative magnitude.

Multiple-Choice Explanations (continued)

17. A — 2.3 Structure of Ionic Solids
The count ratio 6:4 reduces to the charge-balancing cation:anion ratio in Mg_3P_2.

18. C — 2.3 Structure of Ionic Solids
An ionic sample is neutral when the sum of all cation charges equals the magnitude of the sum of all anion charges; the particle counts need not be equal.

19. C — 2.3 Structure of Ionic Solids
The ions exist in both phases. They are locked at lattice sites in the solid but mobile and able to carry charge in the liquid.

20. B — 2.3 Structure of Ionic Solids
BeO is predicted to be strongest because Be^{2+} and O^{2-} give a larger charge product and short separation. Coulombic attraction increases with charge product and decreases with separation.

21. C — 2.3 Structure of Ionic Solids
Smaller ions can approach more closely, decreasing r in the Coulombic interaction and strengthening attraction.

22. B — 2.3 Structure of Ionic Solids
When planes shift, ions of the same charge can be brought next to one another. Their repulsion drives a crack through the brittle lattice.

23. B — 2.3 Structure of Ionic Solids
Melting destroys long-range positional order and permits ion motion; it does not require neutralizing the ions.

24. A — 2.3 Structure of Ionic Solids
Dissolution separates the ions and allows them to migrate through solution in response to an electric field.

Multiple-Choice Explanations (continued)

25. A — 2.3 Structure of Ionic Solids
A missing cation leaves excess negative charge. Charge compensation requires removing sufficient negative charge or adding equivalent positive charge.

26. C — 2.4 Structure of Metals and Alloys
Guest atoms occupying ordinary host lattice sites form a substitutional alloy; the similar radii support replacement without a new particle type in the gaps.

27. D — 2.4 Structure of Metals and Alloys
Much smaller guest atoms occupying spaces between host-metal atoms define an interstitial alloy.

28. C — 2.4 Structure of Metals and Alloys
Different-sized atoms disturb the repeating lattice, making it more difficult for planes and dislocations to move under stress.

29. D — 2.4 Structure of Metals and Alloys
Metal cores remain near lattice sites, whereas delocalized valence electrons can move through the solid and carry current.

30. A — 2.4 Structure of Metals and Alloys
The delocalized electron sea continues to attract positive metal cores after layers shift, allowing plastic deformation.

31. B — 2.4 Structure of Metals and Alloys
Comparable radii permit one metal to replace the other at ordinary lattice sites, giving a substitutional solid solution.

32. B — 2.4 Structure of Metals and Alloys
Metallic alloys retain a mobile electron sea and therefore conduct in the solid state, unlike an ideal ionic crystal with fixed ions.

Multiple-Choice Explanations (continued)

33. C — 2.4 Structure of Metals and Alloys
Mechanical properties depend on ease of lattice motion. Distortion can reduce ductility even when metallic conductivity remains.

34. D — 2.5 Lewis Diagrams
Add the valence electrons from every atom: 2(7) + 6 = 20.

35. A — 2.5 Lewis Diagrams
The completed structure has 8 lone pairs because O has two lone pairs and each Br has three.

36. D — 2.5 Lewis Diagrams
XeF_4 is a familiar octet-rule exception: Xe has four bonds and two lone pairs, exceeding an octet.

37. C — 2.5 Lewis Diagrams
The total electron budget controls every later step. Add electrons for negative charge and subtract them for positive charge.

38. A — 2.5 Lewis Diagrams
Hydrogen follows the duet rule and normally makes one bond, so it cannot connect two or more terminal atoms.

39. C — 2.5 Lewis Diagrams
Three bonds contribute six shared electrons around the central atom, and the lone pair contributes two more, giving an octet.

40. D — 2.5 Lewis Diagrams
A lone pair on an adjacent atom can be shared to form a multiple bond, increasing the central atom's electron count while conserving electrons.

Multiple-Choice Explanations (continued)

41. B — 2.5 Lewis Diagrams
Second-period atoms have only the 2s and 2p valence orbitals and cannot accommodate more than eight electrons in an AP Lewis model.

42. B — 2.5 Lewis Diagrams
The standard construction procedure places remaining electrons on the central atom, then considers multiple bonds if the central atom still lacks an octet.

43. D — 2.6 Resonance and Formal Charge
Average bond order is total bond order divided by equivalent bond positions: 5/3 = 1.67.

44. B — 2.6 Resonance and Formal Charge
Resonance contributors differ only in electron placement. The actual species is one resonance hybrid with delocalized electron density.

45. D — 2.6 Resonance and Formal Charge
Formal charge assigns all lone-pair electrons and half of each shared pair to the atom, then compares that assignment with the free atom's valence count.

46. A — 2.6 Resonance and Formal Charge
Major contributors normally minimize formal charges and unfavorable charge separation while preserving appropriate octets.

47. D — 2.6 Resonance and Formal Charge
Equal bond lengths at positions drawn differently in individual contributors are evidence that the π bonding is delocalized in the actual structure.

48. A — 2.6 Resonance and Formal Charge
Formal charges are bookkeeping assignments. Their algebraic sum must reproduce the molecule's or ion's overall charge.

Multiple-Choice Explanations (continued)

49. D — 2.6 Resonance and Formal Charge
Negative formal charge is generally more stable on a more electronegative atom, provided octets and charge magnitudes are otherwise comparable.

50. B — 2.6 Resonance and Formal Charge
Resonance contributors are not separate substances. The double-headed resonance symbol connects alternative Lewis representations of one electronic structure.

51. D — 2.6 Resonance and Formal Charge
Equivalent contributors have the same formal-charge pattern and energy, so none is preferred over the others.

52. D — 2.7 VSEPR and Hybridization
2 electron domains with 0 lone pair(s) give linear molecular geometry.

53. A — 2.7 VSEPR and Hybridization
The central atom has 3 electron domains, corresponding to sp^2 hybridization in the AP model.

54. B — 2.7 VSEPR and Hybridization
VSEPR gives bent geometry. Considering bond dipoles and symmetry, the species is polar.

55. A — 2.7 VSEPR and Hybridization
A total of 5 electron domains arranged to minimize repulsion gives T-shaped molecular geometry after lone-pair positions are omitted.

56. C — 2.7 VSEPR and Hybridization
The square pyramidal arrangement determines the vector sum of the bond dipoles; in SF_5^- they do not cancel.

Multiple-Choice Explanations (continued)

57. B — 2.7 VSEPR and Hybridization

Lone pairs occupy more diffuse space near the central atom, so the usual order is lone pair–lone pair > lone pair–bond pair > bond pair–bond pair.

58. C — 2.7 VSEPR and Hybridization

The H—C bond is one σ bond. The C≡N triple bond contains one σ and two π bonds, giving two σ and two π in total.

59. D — 2.7 VSEPR and Hybridization

Four domains adopt a tetrahedral electron-domain arrangement. Omitting the lone-pair position leaves three bonded atoms in a trigonal-pyramidal molecular geometry.

60. B — 2.7 VSEPR and Hybridization

With two bonds and two lone pairs, only the bonded atoms define a bent molecular shape. Four bonds and no lone pairs give a tetrahedral molecule.

Section II Scoring Guidelines and Worked Solutions

Suggested total: 46 points. Award points independently unless a criterion explicitly depends on an earlier result.

Question 1 — Bromate Ion: Lewis Structure, Resonance, and Ionic Bonding

Scoring criterion	Points
Calculates 26 valence electrons.	1
Draws a valid contributor with the correct atom connectivity and complete terminal-atom octets.	1
Shows the appropriate Br=O and Br—O bond pattern, lone pairs, and formal charges summing to −1.	1
States 3 equivalent contributors.	1
Calculates average bond order 5/3 = 5/3.	1
Uses the equal, intermediate 165 pm distances as evidence for delocalized bonding.	1
Identifies trigonal pyramidal geometry and sp^3 hybridization.	1
Justifies the geometry using 4 electron domains and 1 lone pair on the central atom.	1
Predicts $Ba(BrO_3)_2$ has the greater lattice-energy magnitude.	1
Justifies the lattice prediction using higher cation charge and/or smaller ion separation.	1

Worked solution

(a) The valence-electron total is 26 electrons after the ionic charge is included.

(b) A lowest-formal-charge contributor uses the required mix of Br=O and Br—O bonds. Lone pairs complete the terminal O octets, the central atom has 1 lone pair, and the formal charges add to −1.

(c) The multiple-bond position can be placed equivalently at 3 sites, so 3 contributors have the same energy.

(d) The total bond order is 5; distributed across 3 equivalent positions, the average is 5/3 = 5/3.

(e) Every measured bond is 165 pm, between the localized single value (175 pm) and double value (156 pm). Equal intermediate lengths support a resonance hybrid rather than a fixed single/double pattern.

(f) The central atom has 4 electron domains (3 bonding and 1 lone-pair domain). The molecular geometry is trigonal pyramidal, and the AP hybridization assignment is sp^3.

(g) $Ba(BrO_3)_2$ has the greater predicted lattice-energy magnitude. Its cation has the larger charge and generally a smaller radius, strengthening Coulombic attraction to BrO_3^- under comparable structural assumptions.

Question 2 — Potential-Energy Investigation: B—F and B—Cl

Scoring criterion	Points
Identifies B—F as stronger from the larger dissociation energy.	1
Places the B—F minimum at 130 pm and the B—Cl minimum at 175 pm in correct left–right order.	1
Places the minima at relative depths consistent with 613 and 456 kJ·mol^{-1}.	1
Shows a steep repulsive wall and a common zero-energy separated-atom limit.	1
Obtains $\Delta E = -456$ kJ·mol^{-1} for formation of B—Cl.	1
Calculates 0.250(613) = 153.2 kJ for dissociation of B—F.	1
States the net force is zero at the minimum.	1
Connects zero force to zero slope, $F = -dE/dr$.	1
Relates the shorter equilibrium distance to stronger orbital overlap/attraction.	1
Connects the deeper minimum with greater energy needed to separate the atoms.	1

Worked solution

(a) B—F is stronger because its dissociation energy is larger (613 kJ·mol^{-1} versus 456 kJ·mol^{-1}).

(b) Both curves approach zero at large separation. The B—F minimum is located at 130 pm and −613 kJ·mol^{-1}; the B—Cl minimum is at 175 pm and −456 kJ·mol^{-1}. Each curve rises sharply at very short distance.

(c) Bond formation moves from zero to the minimum, so $\Delta E = -456$ kJ·mol^{-1}.

(d) $q = nD = 0.250 \text{ mol} \times 613 \text{ kJ·mol}^{-1} = 153.2$ kJ.

(e) At the minimum, $dE/dr = 0$, so $F = -dE/dr = 0$. Attractive and repulsive effects balance.

(f) The shorter bond permits effective valence-orbital overlap at a smaller separation. Stronger attraction lowers the bonded state farther below the separated-atom reference, producing the deeper well.

Question 3 — Platinum–Carbon Alloy: Particle Model and Properties

Scoring criterion	Points
Classifies the alloy as interstitial.	1
Uses the radius comparison (139 pm versus 70 pm) appropriately.	1
Connects ordinary lattice sites to substitutional behavior or gaps to interstitial behavior.	1
Describes a regular host lattice with a distinguishable guest population.	1
Places the guest atoms at the correct type of site.	1
Attributes conductivity to mobile, delocalized valence electrons.	1
Predicts greater hardness or reduced ease of deformation.	1
Explains that guest atoms distort the lattice and impede layer/dislocation motion.	1
States that metallic bonding is nondirectional.	1
Explains that shifted metal cores remain attracted to the delocalized electron sea.	1

Worked solution

(a) The alloy is interstitial.

(b) The radii are 139 pm for Pt and 70 pm for C. The prompt places guest atoms at interstitial holes, consistent with their much smaller radius.

(c) Draw a regular array of Pt particles and show a smaller number of C particles at the spaces between the normal sites. Pure Pt would show only one particle type at ordinary sites.

(d) The positive metal cores remain surrounded by mobile, delocalized valence electrons. These electrons respond to an electric field and carry current through the solid.

(e) The guest atoms disrupt the repeating host lattice and obstruct movement of layers or dislocations, so more stress is required for permanent deformation.

(f) Metallic bonding is nondirectional. When cores shift, the delocalized electron sea continues to attract them, so cohesion is not tied to one fixed pairwise bond direction.

Question 4 — Lewis Structure and VSEPR of SF_5^-

Scoring criterion	Points
Calculates 42 valence electrons.	1
Draws a complete valid Lewis diagram with correct lone pairs/formal charges.	1
Identifies square pyramidal geometry and sp^3d^2 hybridization.	1
Identifies the species as polar and justifies with the vector sum of bond dipoles.	1

Worked solution

(a) The electron total is 42. Place the least electronegative nonterminal atom at the center, complete terminal octets, and place remaining electrons on the central atom; formal charges must sum to the species charge.

(b) Counting bonding and lone-pair domains gives square pyramidal molecular geometry and sp^3d^2 hybridization in the AP model.

(c) The species is polar; its bond-dipole vectors do not cancel in the stated geometry.

Question 5 — Ionic Lattice Attractions and Conductivity

Scoring criterion	Points
Predicts Mg_3N_2 has the greater lattice-energy magnitude.	1
Justifies the prediction: Mg^{2+} and N^{3-} give the larger charge product.	1
States that ions are fixed at lattice sites in the solid.	1
States that ions become mobile in the molten state and carry charge.	1

Worked solution

(a) Mg_3N_2 is predicted to have the greater lattice-energy magnitude because Mg^{2+} and N^{3-} give the larger charge product. Coulombic attraction grows with charge product and decreases with separation.

(b) The ions in solid Mg_3N_2 vibrate about fixed sites and cannot transport charge through the sample. Melting frees the ions to move in an electric field.

Question 6 — Resonance in Hydrogen Carbonate, HCO_3^-

Scoring criterion	Points
Gives two principal contributors for the two nonprotonated C—O positions with appropriate formal charges.	1
States an average bond order of 3/2 for those two bonds.	1
Explains that the actual species is one resonance hybrid, not rapidly interconverting structures.	1
Connects equal intermediate lengths to delocalized π bonding.	1

Worked solution

(a) The principal description uses two principal contributors for the two nonprotonated C—O positions; only electron placement changes, and the formal charges sum to the ion charge.

(b) The average bond order is 3/2 for those two bonds for the stated equivalent positions.

(c) Equal lengths intermediate between localized single and multiple bonds show that π electron density is delocalized in one resonance hybrid.

Question 7 — Bonding and Properties of Boron Carbide, B_4C

Scoring criterion	Points
Classifies the sample as network covalent.	1
Uses the structural fact that many strong covalent bonds must be disrupted to deform or melt it.	1
Makes a property prediction consistent with the bonding model.	1
Explains electrical behavior using the presence or absence of mobile charge carriers.	1

Worked solution

(a) Boron Carbide, B_4C is classified as network covalent.

(b) The key structural reason is that many strong covalent bonds must be disrupted to deform or melt it; the predicted hardness/melting behavior follows from the energy needed to disrupt that structure.

(c) The sample is predicted to be a poor electrical conductor because its electrons are localized in covalent bonds and it contains no mobile ions.

Assessment Blueprint

Unit 2 topic	MCQs	FRQ emphasis
2.1 Types of Chemical Bonds	8	Q7
2.2 Intramolecular Force and Potential Energy	8	Q2
2.3 Structure of Ionic Solids	9	Q1, Q5
2.4 Structure of Metals and Alloys	8	Q3
2.5 Lewis Diagrams	9	Q1, Q4, Q6
2.6 Resonance and Formal Charge	9	Q1, Q6
2.7 VSEPR and Hybridization	9	Q1, Q4

Quality-Control Summary

- Exactly 60 four-choice MCQs with 15 answers in each position
- Exactly seven FRQs: three long (10 points each) and four short (4 points each), totaling 46 points
- All seven current AP Chemistry Unit 2 topics represented
- Student pages contain no key, scoring criteria, topic labels, or solution cues
- Chemical formulas, ion charges, exponents, σ/π symbols, and arrows use publication-ready notation
- Original data, potential-energy graph, particle models, chemical systems, and wording
- Independent-resource disclaimer included; no official logo or authorship implication
- Practice Test 5 cross-checked against the other four batch forms and earlier local exam references