AP CHEMISTRY

UNIT 3 PRACTICE TEST

TEST FORM 5

PROPERTIES OF SUBSTANCES AND MIXTURES

60 Multiple-Choice Questions • Seven Free-Response Questions

Calculator Permitted

General Test Instructions

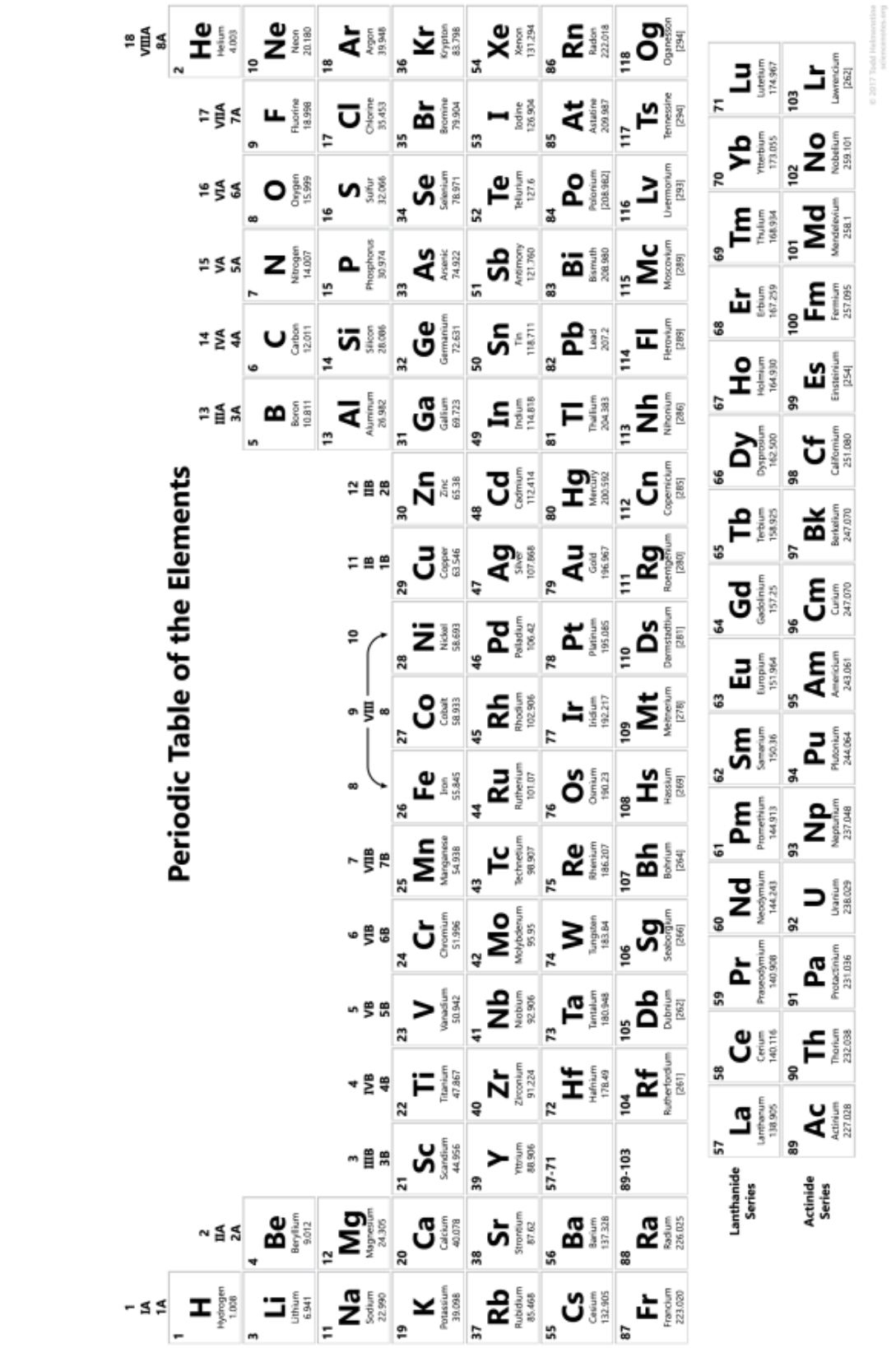
This examination contains only AP Chemistry Unit 3 content. It is designed as a full-length, high-volume unit assessment rather than a content-balanced simulation of the complete AP Chemistry course.

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

60 Questions • Suggested time: 90 minutes • Calculator permitted

Select the one best answer for each question. Record each answer on the answer grid after you have considered all four choices.

1. At 25 °C, which pure liquid is expected to have the greatest surface tension?

A. CH_3OH
B. CH_3OCH_3
C. C_4H_{10}
D. H_2O

2. Which structural feature allows ethanol molecules to form hydrogen bonds with one another?

A. A C–C single bond
B. An O–H bond
C. A C–H bond
D. A nonbonding pair on carbon

3. Which hydrocarbon is expected to have the strongest London dispersion forces?

A. CH_4
B. C_2H_6
C. C_4H_{10}
D. All have the same value because they are nonpolar

4. A pure liquid is heated at constant external pressure while it boils. Which statement is correct during the constant-temperature plateau?

A. Average kinetic energy increases while potential energy decreases.
B. Average kinetic energy decreases while potential energy increases.
C. Average kinetic energy remains constant while potential energy increases.
D. Both average kinetic energy and potential energy remain constant.

5. Which substance is most likely to form a brittle solid that conducts electricity when molten but not when solid?

A. SiO_2
B. MgO
C. I_2
D. Cu

6. Diamond has an exceptionally high melting point primarily because it contains

A. large ions held together by ion-dipole attractions
B. an extended covalent network of strong C–C bonds
C. discrete nonpolar molecules with strong dipole-dipole attractions
D. metal cations surrounded by mobile electrons

7. Why does a copper wire conduct electricity without melting?

A. Copper atoms become Cu^{2+} ions that migrate through the wire.
B. Covalent bonds repeatedly break and reform along the wire.
C. Water molecules hydrate mobile ions in the solid.
D. Delocalized valence electrons move through the metal lattice.

8. At the same temperature, which liquid is expected to have the highest vapor pressure?

A. A liquid with extensive hydrogen bonding
B. A liquid made of large polar molecules
C. A liquid with strong dipole–dipole attractions
D. A liquid made of small nonpolar molecules

9. Which pure substance is held together in the condensed phase only by London dispersion forces?

A. HF
B. Ar
C. SO_2
D. NaF

10. Which statement best describes condensation of a vapor at constant pressure?

A. Energy is absorbed because particles move farther apart.
B. The average molar mass of the particles decreases.
C. All intermolecular attractions are broken.
D. Energy is released as intermolecular attractions form.

11. Which substance is expected to have the lowest normal boiling point?

A. H_2O
B. NH_3
C. Ne
D. CH_3CH_2OH

Section I Answer Grid

Record one letter for each question. This page may be detached or copied for student use.

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

7 Questions • Suggested time: 105 minutes • Total: 46 points

Questions 1–3 are 10-point extended responses. Questions 4–7 are 4-point short responses. Show calculations, units, and chemical reasoning where requested.

Question 1: Intermolecular forces, vaporization, and distillation (10 points)

Equal 25.0 g samples of acetone, CH_3COCH_3, and propan-1-ol, $CH_3CH_2CH_2OH$, are placed in identical open dishes at 25 °C. Propan-1-ol has the higher normal boiling point. The liquids are later separated from a mixture by simple distillation at 1.00 atm.

(a) (2 points) Identify the strongest intermolecular force present between propan-1-ol molecules and explain why it is not present between acetone molecules.

(b) (2 points) Predict which liquid evaporates more rapidly at first. Justify the prediction in terms of vapor pressure and intermolecular forces.

(c) (2 points) Describe the changes in average kinetic energy and potential energy while a pure sample of propan-1-ol boils at constant pressure.

(d) (2 points) In a particle representation of liquid propan-1-ol, state how two neighboring O–H groups should be oriented to show a hydrogen bond.

(e) (2 points) During simple distillation of the acetone–propan-1-ol mixture, state which component is collected first and justify the answer.

TEACHER MATERIALS

ANSWER KEY, EXPLANATIONS, AND SCORING GUIDELINES

AP Chemistry Unit 3 Practice Test — Form 5

Properties of Substances and Mixtures

Teacher use only. The multiple-choice explanations identify the central chemical principle. Free-response scoring awards points for scientifically correct reasoning, not for matching the wording of the sample response.

Section I Answer Key

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

Section II Scoring Guidelines and Worked Solutions

Question 1: Intermolecular forces, vaporization, and distillation (10 points)

Equal 25.0 g samples of acetone, CH_3COCH_3, and propan-1-ol, $CH_3CH_2CH_2OH$, are placed in identical open dishes at 25 °C. Propan-1-ol has the higher normal boiling point. The liquids are later separated from a mixture by simple distillation at 1.00 atm.

(a) (2 points) Scoring guideline and sample solution: Hydrogen bonding is the strongest intermolecular force between propan-1-ol molecules. Its O–H group contains H bonded to highly electronegative O and the O atom has lone pairs. Acetone has a polar C=O group and therefore dipole-dipole attractions, but it has no O–H, N–H, or F–H bond and cannot hydrogen-bond to another acetone molecule.

(b) (2 points) Scoring guideline and sample solution: Acetone evaporates more rapidly. Its intermolecular attractions are weaker overall because acetone lacks hydrogen bonding. At the same temperature it has a higher vapor pressure, so a greater fraction of acetone molecules escape the liquid surface per unit time.

(c) (2 points) Scoring guideline and sample solution: Average kinetic energy remains constant because the temperature is constant during boiling. Potential energy increases because added energy separates molecules and overcomes intermolecular attractions as liquid becomes vapor.

(d) (2 points) Scoring guideline and sample solution: The H atom attached to the O atom of one propan-1-ol molecule should point toward a lone-pair region on the O atom of a neighboring molecule. That orientation shows the attraction between the partially positive H and partially negative O.

(e) (2 points) Scoring guideline and sample solution: Acetone is collected first because it has the lower normal boiling point and is more volatile. Its vapor is enriched relative to the liquid mixture, so it reaches the condenser preferentially at the lower temperature.

Science-practice emphasis: Model analysis and molecular-level explanation.

Question 2: Gas mixtures, kinetic molecular theory, and real-gas behavior (10 points)

A rigid 1.25 L vessel at 325 K contains 0.0350 mol $N_2(g)$ and 0.0150 mol Ar(g). Assume ideal behavior unless a part states otherwise. Use $R = 0.08206\ L{\cdot}atm{\cdot}mol^{-1}{\cdot}K^{-1}$.

(a) (2 points) Scoring guideline and sample solution: $n_{total} = 0.0350\ mol + 0.0150\ mol = 0.0500\ mol$. $P_{total} = nRT/V = (0.0500)(0.08206)(325)/(1.25) = 1.07\ atm$.

(b) (2 points) Scoring guideline and sample solution: $P_{ar} = n_{ar}RT/V = (0.0150)(0.08206)(325)/(1.25) = 0.320$ atm. Equivalently, $X_{ar} = 0.0150/0.0500 = 0.300$ and $P_{ar} = 0.300(1.07\ atm)$.

(c) (2 points) Scoring guideline and sample solution: N_2 and Ar have equal average translational kinetic energies because both are at 325 K. N_2 molecules have the greater average speed because N_2 has the smaller molar mass; at fixed temperature, typical speed is inversely related to the square root of molar mass.

(d) (2 points) Scoring guideline and sample solution: The actual pressure is likely to be less than the ideal-gas prediction. At lower temperature and high density, attractive forces between particles pull them away from the container walls and reduce the force of wall collisions.

(e) (2 points) Scoring guideline and sample solution: Use the unrounded initial pressure. $P_2 = nRT/V = (0.0500\ mol)(0.08206\ L{\cdot}atm{\cdot}mol^{-1}{\cdot}K^{-1})(400.\ K)/(1.25\ L) = 1.31\ atm$.

Science-practice emphasis: Mathematical routines and kinetic-model reasoning.

Assessment Blueprint and Quality-Control Summary

This form samples all Unit 3 topic families, balancing conceptual reasoning, quantitative work, model interpretation, and experimental reasoning.

Unit 3 topic	MCQs	Question numbers
Intermolecular forces and properties	5	1, 2, 3, 9, 11
Liquids, gases, and phase changes	4	4, 8, 10, 12
Properties of solids	3	5, 6, 7
Ideal gas law	4	13, 14, 16, 24
Kinetic molecular theory	3	15, 17, 18
Deviation from ideal-gas behavior	3	19, 20, 21
Gas mixtures	2	22, 23
Solutions and mixtures	3	25, 26, 35
Representations of solutions	3	27, 28, 29
Solubility	3	30, 31, 33
Dilution	1	32
Molarity	1	34
Separation of mixtures	5	36, 39, 41, 42, 43
Chromatography	3	37, 38, 40
Electromagnetic radiation and spectroscopy	5	44, 45, 46, 47, 48
Properties of photons	3	49, 50, 51
Spectroscopy and electronic transitions	1	52
Beer–Lambert law	8	53, 54, 55, 56, 57, 58, 59, 60

Free-Response Coverage

Question	Points	Primary evidence / skill
1	10	Intermolecular forces, vaporization, and distillation; Model analysis and molecular-level explanation
2	10	Gas mixtures, kinetic molecular theory, and real-gas behavior; Mathematical routines and kinetic-model reasoning
3	10	Preparation and particle-level interpretation of an ionic solution; Quantitative representation and particulate modeling
4	4	Paper chromatography of two pigments; Data analysis and model-based inference
5	4	Photon Energy from an Electronic Transition; Mathematical modeling of an electronic transition and emitted photon
6	4	Beer–Lambert analysis of a colored solution; Quantitative analysis of experimental measurements
7	4	Using physical properties to classify a solid; Experimental design and evidence-based argumentation

Quality-Control Summary

Multiple-choice count	60 questions; four choices per question
Answer-position balance	A: 15; B: 15; C: 15; D: 15
Free-response count	7 questions; 46 points total (10, 10, 10, 4, 4, 4, 4)
Student / teacher separation	All answers and worked solutions appear after the teacher divider
Notation check	Chemical subscripts, superscripts, charges, state symbols, and Unicode reaction arrows are used where applicable
Independence statement	No College Board logo, paper code, candidate box, barcode, or endorsement claim is included