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# Answer Key

AP Chemistry Unit-Organized MCQ - Form A

## Source-Driven Design Notes

The supplied 2013, 2018, 2019, 2021, 2023, and 2025 materials were reviewed for recurring question structure, data presentation, topic vocabulary, and response format. The resulting exam uses 60 original four-choice questions, short scientific prompts, equations, tables, quantitative estimates, and explanation-based distractors. It does not reproduce source questions.

Vocabulary control: chemistry terminology was limited to language represented in the supplied materials and standard equation-sheet notation. Requested exclusions were applied throughout the question set.

## Progression Model

Within each unit, question counts are weighted toward later tiers: Core uses direct concept checks, Application uses a single model or calculation, and Challenge uses linked representations or multiple reasoning steps. Unit 3 and Unit 8 receive additional questions because the source exams repeatedly use intermolecular-force, solution, and acid-base contexts.

# Quick Answer Key

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

Unit 1

# Atomic Structure and Properties

**CORE** 1 question · Direct concept check

## 1. C

Core

A sample of element X contains two isotopes. The relative abundances are shown in the table. What is the average molar mass of X?

The weighted average is (0.692)(62) + (0.308)(64) = 62.616 g mol^-1, which rounds to 62.6 g mol^-1.

**APPLICATION** 1 question · Single-step data and model use

## 2. D

Application

Which of the following is the ground-state electron configuration of S2-?

A sulfur atom has 16 electrons. The 2- ion has gained two electrons, giving 18 electrons and the configuration [Ne] 3s2 3p6.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

## 3. B

Challenge

The first ionization energy of Mg is greater than that of Na. Which of the following best explains the difference?

Na and Mg have valence electrons in the same principal energy level. Mg has a greater nuclear charge with similar shielding, so its valence electrons experience a stronger attraction.

## 4. B

Challenge

The mass spectrum of chlorine has its largest peak at mass number 35. The atomic number of chlorine is 17. How many neutrons are in the isotope represented by the largest peak?

The number of neutrons equals the mass number minus the atomic number: 35 - 17 = 18.

## 5. A

Challenge

The first four ionization energies of an element are shown. Which valence-electron configuration is most consistent with the data?

The large increase between the second and third ionization energies shows that two electrons are removed before a core electron must be removed. The valence configuration is ns2.

Unit 2

# Molecular and Ionic Compound Structure and Properties

**CORE** 1 question · Direct concept check

### 6. A

Core

Which of the following best describes the molecular geometry of CO2?

The central carbon atom has two bonding regions and no lone pairs, so the O-C-O arrangement is linear.

**APPLICATION** 1 question · Single-step data and model use

### 7. A

Application

Which of the following carbon-halogen bonds is the most polar?

Fluorine has the greatest electronegativity of the halogens listed, so the electronegativity difference in C-F is greatest.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

### 8. B

Challenge

The Lewis diagram of H2O has two O-H bonds and two lone pairs on O. Which molecular geometry is consistent with the diagram?

Four electron domains surround O, and two are lone pairs. The positions of the two bonded H atoms form a bent molecular geometry.

### 9. C

Challenge

MgO has a much higher melting point than NaF. Which of the following best explains the difference?

MgO contains Mg2+ and O2- ions, whereas NaF contains Na+ and F- ions. Greater ionic charges produce stronger attractions and a higher melting point.

### 10. D

Challenge

Which statement best describes the bonding in CO32-?

The double bond can be drawn to any one of the three oxygen atoms. The three equivalent resonance structures give three equivalent C-O bonds.

Unit 3

# Intermolecular Forces and Properties

**CORE** 2 questions · Direct concept check

## 11. B

Core

Samples of He(g) and Ne(g) are at the same temperature. Which statement about the average kinetic energy of the particles is correct?

Average kinetic energy depends only on absolute temperature. Because both gases are at the same temperature, their particles have the same average kinetic energy.

## 12. C

Core

$CH_3OH(l)$ has a higher boiling point than $CH_3OCH_3(l)$. Which of the following best explains the difference?

$CH_3OH$ molecules contain O-H bonds and form hydrogen bonds with one another. $CH_3OCH_3$ does not have an O-H bond and cannot form the same intermolecular hydrogen-bonding network.

**APPLICATION** 4 questions · Single-step data and model use

## 13. A

Application

Equal-volume samples of the gases shown are at the same temperature and pressure. Which sample has the greatest mass?

Equal volumes at the same temperature and pressure contain equal numbers of moles. $CO_2$ has the greatest molar mass, so sample 1 has the greatest mass.

## 14. D

Application

At the same high temperature and low pressure, He(g) behaves more ideally than $NH_3(g)$. Which statement best explains the observation?

$NH_3$ molecules have significant intermolecular attractions, including hydrogen bonding. The much weaker attractions among He atoms make He more closely follow ideal-gas behavior.

## 15. A

Application

The boiling points of four liquids are shown. At the same temperature below all four boiling points, which liquid has the greatest vapor pressure?

The liquid with the lowest boiling point has the weakest intermolecular attractions and the greatest vapor pressure at a given temperature.

## 16. C

Application

A 25.0 mL sample of 0.200 M $KNO_3(aq)$ is diluted with water to a total volume of 100.0 mL. What is the final concentration?

The moles of solute remain constant. $M_1V_1 = M_2V_2$ gives $M_2 = (0.200\ M)(25.0\ mL)/(100.0\ mL) = 0.0500\ M$.

**CHALLENGE** 6 questions · Multi-step reasoning and linked representations

## 17. B

Challenge

A solution has an absorbance of 0.80 when its concentration is 0.100 M. Under the same conditions, an unknown solution has an absorbance of 0.40. What is the concentration of the unknown?

Absorbance is directly proportional to concentration under the same conditions. Halving the absorbance corresponds to halving the concentration to 0.050 M.

### 18. D

Challenge

In a paper chromatography experiment, substance Q travels farther than substance R. Which statement is most consistent with the observation?

A substance that is more strongly attracted to the mobile phase and less strongly retained by the stationary phase travels farther.

### 19. C

Challenge

Which description best represents NaCl(s) after it dissolves in water?

NaCl is an ionic solid. It dissolves by separating into Na+ and Cl- ions that are surrounded by water molecules while preserving the 1:1 formula-unit ratio.

### 20. C

Challenge

The solubility of KNO3 is 50 g per 100 g H2O at 60°C and 30 g per 100 g H2O at 20°C. A saturated solution containing 100 g of water at 60°C is cooled to 20°C. What mass of KNO3 is expected to crystallize?

The dissolved mass decreases from 50 g to 30 g per 100 g water, so 20 g crystallizes.

### 21. D

Challenge

A gas occupies 2.0 L at 1.0 atm and 300 K. It is compressed to 1.0 L and heated to 600 K. What is the final pressure?

Using P1V1/T1 = P2V2/T2 gives P2 = (1.0 atm)(2.0 L)(600 K)/[(300 K)(1.0 L)] = 4.0 atm.

### 22. B

Challenge

During a phase transition on a heating curve, energy is added while the temperature remains constant. Which statement best describes the particles during this interval?

At constant temperature, average kinetic energy remains constant. The added energy increases potential energy as intermolecular attractions are overcome.

Unit 4

# Chemical Reactions

**CORE** 1 question · Direct concept check

## 23. A

Core

Which of the following is the net ionic equation for the formation of AgCl(s) when AgNO3(aq) and NaCl(aq) are mixed?

Na+ and NO3- are spectator ions. The reacting species are Ag+ and Cl-, which form insoluble AgCl(s).

**APPLICATION** 2 questions · Single-step data and model use

## 24. B

Application

N2(g) + 3 H2(g) → 2 NH3(g). If 2.0 mol N2 and 3.0 mol H2 react completely, which statement is correct?

Three moles of H2 react with one mole of N2 to form two moles of NH3. H2 is limiting; 3.0 mol H2 forms 2.0 mol NH3.

## 25. C

Application

H2SO4(aq) + 2 NaOH(aq) → Na2SO4(aq) + 2 H2O(l). What volume of 0.100 M NaOH is required to react completely with 25.0 mL of 0.100 M H2SO4?

The acid sample contains 0.00250 mol H2SO4 and requires 0.00500 mol NaOH. At 0.100 M, the required volume is 0.0500 L, or 50.0 mL.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

## 26. B

Challenge

Excess SO42-(aq) is added to 25.0 mL of a BaCl2(aq) solution. After filtering and drying, 0.583 g of BaSO4(s) is collected. The molar mass of BaSO4 is 233 g mol-1. What was the concentration of BaCl2?

0.583 g/233 g mol^-1 = 0.00250 mol BaSO4, equal to the initial moles of Ba2+. Dividing by 0.0250 L gives 0.100 M.

## 27. A

Challenge

2 Al(s) + 3 Cu2+(aq) → 2 Al3+(aq) + 3 Cu(s). Which statement correctly describes the reaction?

Al loses electrons as its oxidation number increases from 0 to +3. Cu2+ gains electrons as its oxidation number decreases from +2 to 0.

## 28. D

Challenge

The reaction A2 + 3 B2 → 2 AB3 occurs in a closed container. Initially, 4 particles of A2 and 9 particles of B2 are present. Which particles remain after the reaction goes to completion?

Nine B2 particles react with three A2 particles to form six AB3 particles. One A2 particle remains.

Unit 5

# Kinetics

**CORE** 1 question · Direct concept check

## 29. B

Core

The initial-rate data for a reaction are shown. Which rate law is consistent with the data?

Doubling [A] makes the rate four times as large, so the reaction is second order in A. Doubling [B] has no effect, so it is zero order in B.

**APPLICATION** 2 questions · Single-step data and model use

## 30. C

Application

Using the data in question 29, what is the value of the rate constant k?

For rate = k[A]^2, k = (2.0 × 10^-3 M s^-1)/(0.10 M)^2 = 0.20 M^-1 s^-1.

## 31. A

Application

A catalyst is added to a reaction at constant temperature. Which statement correctly describes the effect of the catalyst?

A catalyst provides an alternate pathway with lower activation energy for both directions. It does not change reactant or product energies, ΔH, or the equilibrium constant.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

## 32. B

Challenge

A proposed mechanism is shown.Step 1: NO2 + NO2 → NO3 + NO (slow)Step 2: NO3 + CO → NO2 + CO2 (fast)Which species is an intermediate?

NO3 is produced in step 1 and consumed in step 2, and it does not appear in the overall reaction. Therefore, it is an intermediate.

## 33. C

Challenge

For a first-order reaction, [A] decreases from 0.80 M to 0.40 M in 20 s. What will [A] be after a total of 60 s?

The half-life is 20 s. After three half-lives, 0.80 M becomes 0.40 M, then 0.20 M, then 0.10 M.

## 34. D

Challenge

Which statement best explains why increasing temperature usually increases the rate constant of a reaction?

At higher temperature, the energy distribution shifts so that a greater fraction of collisions has energy equal to or greater than the activation energy.

Unit 6

# Thermodynamics

**CORE** 1 question · Direct concept check

## 35. B

Core

A reaction warms 100.0 g of water from 20.0°C to 30.0°C. The specific heat capacity of water is 4.18 J g-1 °C-1. How much heat is absorbed by the water?

q = mcΔT = (100.0 g)(4.18 J g^-1 °C^-1)(10.0°C) = 4.18 × 10^3 J = 4.18 kJ.

**APPLICATION** 2 questions · Single-step data and model use

## 36. C

Application

C(s) + O2(g) → CO2(g), ΔH° = -394 kJ mol-1CO(g) + 1/2 O2(g) → CO2(g), ΔH° = -283 kJ mol-1What is ΔH° for C(s) + 1/2 O2(g) → CO(g)?

Add the first reaction to the reverse of the second. The resulting enthalpy is -394 + 283 = -111 kJ mol^-1.

## 37. B

Application

Use the average bond enthalpies H-H = 436 kJ mol-1, Cl-Cl = 243 kJ mol-1, and H-Cl = 431 kJ mol-1. Estimate ΔH for H2(g) + Cl2(g) → 2 HCl(g).

Bonds broken require 436 + 243 = 679 kJ mol^-1. Bonds formed release 2(431) = 862 kJ mol^-1. ΔH = 679 - 862 = -183 kJ mol^-1.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

## 38. A

Challenge

For which process is ΔS expected to be positive?

The production of a gas from solids greatly increases the number of accessible particle arrangements, so ΔS is positive.

## 39. D

Challenge

For CH4(g) + 2 O2(g) → CO2(g) + 2 H2O(l), the standard heats of formation in kJ mol-1 are CH4 = -75, O2 = 0, CO2 = -394, and H2O(l) = -286. What is ΔH° for the reaction?

ΔH° = ΣΔHf°(products) - ΣΔHf°(reactants) = [-394 + 2(-286)] - [-75] = -891 kJ mol^-1.

## 40. B

Challenge

On a potential energy diagram, the products are 50 kJ mol-1 lower in energy than the reactants. Which statement is correct?

ΔH equals product energy minus reactant energy. Products 50 kJ mol^-1 lower give ΔH = -50 kJ mol^-1, so the reaction is exothermic.

Unit 7

# Equilibrium

**CORE** 1 question · Direct concept check

## 41. A

Core

For N2(g) + 3 H2(g) □ 2 NH3(g), which expression is equal to Kc?

Each equilibrium concentration is raised to its stoichiometric coefficient, with products in the numerator and reactants in the denominator.

**APPLICATION** 2 questions · Single-step data and model use

## 42. C

Application

For a reaction mixture at a particular temperature, Q is less than K. Which change occurs as the system approaches equilibrium?

When Q < K, the mixture contains too little product relative to equilibrium, so the net reaction proceeds toward products.

## 43. B

Application

2 NO2(g) □ N2O4(g). At constant temperature, the volume of an equilibrium mixture is decreased. What is the initial response?

Decreasing volume increases pressure. The system responds by shifting toward the side with fewer moles of gas, which is the product side.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

## 44. D

Challenge

For A(g) □ B(g), Kc = 4.0. Initially, [A] = 1.0 M and [B] = 0. What is [A] at equilibrium?

Let x convert to B. Kc = x/(1.0 - x) = 4.0, so x = 0.80 M and [A]eq = 0.20 M.

## 45. B

Challenge

For A(g) □ 2 B(g), K = 5.0 at a certain temperature. What is K for 2 B(g) □ A(g) at the same temperature?

Reversing a reaction takes the reciprocal of the equilibrium constant: Kreverse = 1/5.0 = 0.20.

## 46. C

Challenge

Equal volumes of 0.020 M AgNO3(aq) and 0.010 M K2CrO4(aq) are mixed. For Ag2CrO4, Ksp = 1.0 × 10-12. Which statement is correct immediately after mixing?

After equal-volume mixing, [Ag+] = 0.010 M and [CrO4^2-] = 0.0050 M. Q = (0.010)^2(0.0050) = 5.0 × 10^-7, which is greater than Ksp, so precipitation occurs.

Unit 8

# Acids and Bases

**CORE** 1 question · Direct concept check

## 47. C

Core

What is the pH of 1.0 × 10-3 M HCl(aq)?

HCl is a strong acid, so [H3O+] = 1.0 × 10^-3 M and pH = 3.0.

**APPLICATION** 3 questions · Single-step data and model use

## 48. A

Application

Which statement correctly compares 0.10 M HCl(aq) and 0.10 M HF(aq)?

HCl is a strong acid and ionizes essentially completely. HF is a weak acid and ionizes only partially, so HCl produces a greater [H3O+] and a lower pH.

## 49. C

Application

Which species is the conjugate acid of NH3?

A conjugate acid is formed when a base accepts a proton. NH3 + H+ gives NH4+.

## 50. B

Application

Which mixture forms a buffer?

A buffer contains appreciable amounts of a weak acid and its conjugate base. CH3COOH and CH3COO- satisfy this condition.

**CHALLENGE** 4 questions · Multi-step reasoning and linked representations

## 51. C

Challenge

A buffer contains equal concentrations of CH3COOH and CH3COO-. The pKa of CH3COOH is 4.76. What is the pH of the buffer?

When the weak acid and conjugate base concentrations are equal, log([base]/[acid]) = 0, so pH = pKa = 4.76.

## 52. A

Challenge

The equivalence-point pH of a titration is expected to be 8.7. Which indicator is the best choice?

The indicator range should contain the equivalence-point pH. Only the 8.0-9.6 range includes pH 8.7.

## 53. D

Challenge

At the equivalence point in the titration of a weak acid with a strong base, the pH is usually greater than 7. Which statement best explains why?

At equivalence, the weak acid has been converted to its conjugate base. The conjugate base reacts with water and produces OH-, making the solution basic.

## 54. B

Challenge

At 25°C, Ka for HF is 6.8 × 10-4. What is Kb for F-?

For a conjugate acid-base pair, KaKb = Kw = 1.0 × 10^-14. Kb = (1.0 × 10^-14)/(6.8 × 10^-4) = 1.5 × 10^-11.

Unit 9

# Applications of Thermodynamics

**CORE** 1 question · Direct concept check

### 55. C

Core

For a reaction at 298 K, ΔH° = -100 kJ mol-1 and ΔS° = -200 J mol-1 K-1. What is ΔG°?

Convert ΔS° to -0.200 kJ mol^-1 K^-1. ΔG° = ΔH° - TΔS° = -100 - 298(-0.200) = -40.4 kJ mol^-1.

**APPLICATION** 2 questions · Single-step data and model use

### 56. A

Application

Which combination of signs makes a reaction thermodynamically favorable at all temperatures under standard conditions?

When ΔH° is negative and ΔS° is positive, both terms make ΔG° = ΔH° - TΔS° negative at every temperature.

### 57. D

Application

The standard reduction potentials are shown. What is E° for a galvanic cell that uses Zn(s)/Zn2+(aq) and Cu(s)/Cu2+(aq)?

Cu2+ is reduced at the cathode and Zn is oxidized at the anode. E°cell = 0.34 - (-0.76) = +1.10 V.

**CHALLENGE** 3 questions · Multi-step reasoning and linked representations

### 58. B

Challenge

A galvanic cell operates using Fe(s)/Fe2+(aq) and Cu(s)/Cu2+(aq). The Fe electrode is the anode. Which statement is correct as the cell operates?

Oxidation occurs at the anode: Fe(s) forms Fe2+(aq), so the Fe electrode loses mass. The released electrons flow through the circuit toward the Cu cathode.

### 59. C

Challenge

Ag+(aq) + e- → Ag(s). A current transfers 1.93 × 104 C through an electrolytic cell. Use 9.65 × 104 C mol-1 e- and a molar mass of Ag of 107.9 g mol-1. What mass of Ag is deposited?

The charge is 0.200 mol e-. Because one electron deposits one Ag atom, 0.200 mol Ag forms. The mass is (0.200 mol)(107.9 g mol^-1) = 21.6 g.

### 60. A

Challenge

For a galvanic cell under standard conditions, E° is positive. Which statement must also be true?

ΔG° = -nFE°, so a positive E° gives a negative ΔG°. Also, ΔG° = -RT ln K, so negative ΔG° corresponds to K > 1.