ExamFitter

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

Topic 3.6: Deviation from Ideal Gas Law

Worksheet · AP Chemistry

UNIT 3 · PROPERTIES OF SUBSTANCES AND MIXTURES

On ExamFitter.com: Topic 3.6 Revision Notes · Topic 3.6 Quiz · Previous Worksheet: Topic 3.5 · Next Worksheet: Topic 3.7 · Unit 3: All Topics · AP Chemistry Home

How to Use This Worksheet

Work through the sections in order. Section A checks the two ideal assumptions that fail, Section B builds fluency with the compressibility factor and free volume, and Section C mixes conditions, gases and data in exam style.

Name the dominant effect, attractions or particle volume, before stating any direction.

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

Section A: Recall and Concepts

A1. (a) State the two assumptions about gas particles in the ideal gas law that real gases fail. (b) State the condition that exposes each failure most strongly. (c) State the conditions under which a real gas deviates most, and those under which it behaves most ideally. (d) A real gas sits close to its boiling point inside a high pressure cylinder. Explain, using both failures, why this is close to the worst case for the ideal gas law.

A2. (a) Explain, at particle level, why attractions make the measured pressure lower than the ideal prediction at the same n, V and T. (b) State how the measured volume compares with the ideal

© 2026 ExamFitter.com · Free AP Chemistry worksheets

prediction when attractions dominate at fixed pressure. (c) Explain why the attraction effect grows on cooling, even though the attractions themselves do not change. (d) Name the phase change attractions produce when they win completely, and state what its existence proves.

A3. (a) Define the free volume of a real gas, writing it using V, n and the constant b. (b) State what b measures, and which of a small particle gas and a large particle gas has the larger b. (c) Explain, at particle level, why a smaller free volume makes the measured pressure higher than ideal at the same n, V and T. (d) State how the measured volume compares with the ideal prediction when particle volume dominates at fixed pressure.

A4. The compressibility factor is Z = PV/nRT, from a sample's measured pressure, volume and temperature. (a) State the value of Z for an ideal gas. (b) State what Z < 1 tells you about PV, and name the dominant effect. (c) State what Z > 1 tells you about PV, and name the dominant effect. (d) A gas gives Z = 1.00 at one pressure. Explain why this does not prove it is behaving ideally there.

A5. (a) Rank He, Ne and Xe in order of increasing deviation at the same temperature and pressure, giving the property behind the ranking. (b) Explain why NH_3 deviates much more strongly than CH_4 under the same conditions, naming the interaction responsible. (c) Gas A boils at -196 °C and Gas B at -33 °C. State which behaves more ideally at 25 °C, explaining the ranking from the boiling points. (d) State the pressure and temperature conditions under which water vapour behaves most ideally, with a particle level reason for each.

Section B: Core Practice

Use R = 0.08206 $L \cdot atm \cdot mol^{-1} \cdot K^{-1}$ in this section.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

B1. A rigid container of volume 1.00 L holds 1.00 mol of a gas at 300 K. The measured pressure is 22.0 atm. (a) Calculate the pressure the ideal gas law predicts for this sample. (b) Calculate Z for the sample. (c) State whether the measured pressure sits above or below the ideal prediction, by what percentage, and name the dominant effect.

B2. One mole of a gas at 300 K is held at 200 atm. Its measured volume is 0.150 L. (a) Calculate the volume the ideal gas law predicts. (b) Calculate Z for the sample. (c) State whether the measured volume sits above or below the ideal prediction, name the dominant effect, and explain why it takes over at very high pressures.

B3. For CO_2, b = 0.0427 L/mol. A sample of 3.00 mol of CO_2 sits in a 2.00 L container. (a) Calculate the volume excluded by the particles. (b) Calculate the free volume. (c) Calculate the excluded volume as a percentage of the container volume. (d) The sample is compressed into a 0.500 L container. Recalculate the free volume and the excluded percentage, and state what the two percentages show about when the negligible volume assumption is safe.

B4. Two samples are held at fixed volume and temperature; for each, the ideal gas law predicts 10.0 atm. Sample X exerts 9.20 atm; Sample Y exerts 11.5 atm. (a) Calculate Z for each sample. (b) Name the dominant effect in each sample. (c) For Sample X, explain the measured pressure at particle level, referring to a particle approaching the wall. (d) Sample Y's result comes from very high pressure. State what happens to its Z if the pressure is reduced, and why.

B5. He, N_2, CO_2 and NH_3 are held at the same temperature and pressure. Their boiling points are He -269 °C, N_2 -196 °C, NH_3 -33 °C; CO_2 sublimes at -78 °C. (a) Rank the four gases from most ideal to least ideal. (b) Justify the position of NH_3 using its interactions. (c) Justify the position of He using two separate particle properties. (d) State the single change, to pressure or to temperature, that helps with both failures at once, explaining its effect on each.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

B6. A student makes three claims about a gas with strong attractions. Evaluate each as correct or incorrect, with a reason. (a) "Cooling it towards its boiling point will make it behave more ideally, because the particles move too slowly to collide as often." (b) "At fixed volume and temperature its measured pressure is higher than ideal, because the attractions push the particles apart." (c) "If it is compressed hard enough, the direction of its deviation can reverse."

Section C: Exam Style

C1. One mole of CO_2 is held at 300 K. At 50.0 atm its measured volume is 0.420 L; at 500 atm it is 0.0600 L. Use R = 0.08206 $L{\cdot}atm{\cdot}mol^{-1}{\cdot}K^{-1}$. (a) Calculate the ideal volume at 50.0 atm, and Z at 50.0 atm. (b) Calculate Z at 500 atm. (c) Explain, at particle level, why the dominant effect differs between the two pressures, though the gas and temperature are unchanged. (d) Between these pressures Z passes through 1. Explain what is happening there, and why reporting only that state would misrepresent the gas.

C2. For NH_3, a = 4.17 $L^2{\cdot}atm{\cdot}mol^{-2}$ and b = 0.0371 L/mol; for CH_4, a = 2.25 $L^2{\cdot}atm{\cdot}mol^{-2}$ and b = 0.0428 L/mol. NH_3 boils at -33 °C and CH_4 at -161 °C. (a) State what each constant, a and b, corrects for. (b) A student predicts CH_4 will deviate more, because its b is larger. Evaluate the prediction using both constants. (c) Equal amounts of the two gases sit in identical rigid containers at the same temperature. State which exerts the lower pressure relative to its own ideal prediction, explaining the comparison at particle level. (d) State what each boiling point reveals, and why the higher boiling point gas is further from ideal at room temperature.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

C3. A rigid 5.00 L vessel holds 2.00 mol of a gas at 300 K. The measured pressure is 9.00 atm. Use R = 0.08206 L·atm·mol^{-1}·K^{-1}. (a) Calculate the ideal gas law pressure. (b) Calculate Z. (c) State the percentage by which the measured pressure falls short of ideal, and name the dominant effect. (d) The gas is He, N_2 or NH_3. Identify the most likely gas, justifying your choice against each of the other two. (e) The vessel is heated at constant volume. State what happens to Z, explaining the change at particle level.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Answer Key

A1. (a) That the particles occupy no volume of their own; and that they exert no forces on each other except at the instant of a collision. (b) High pressure exposes the volume failure: compression shrinks the space between particles while the particles keep their size, so their volume becomes a significant fraction of the container. Low temperature exposes the force failure: slow particles linger near each other, so attractions act against less kinetic energy. (c) Greatest deviation at high pressure and low temperature together; most ideal at low pressure and high temperature. (d) Both failures are near their strongest: the particles are packed so closely that their own volume is a large fraction of the container, and they move so slowly that attractions act at nearly full strength.

A2. (a) A particle travelling towards the wall is pulled backward by the particles behind it, so wall collisions are softer and less frequent than the ideal model assumes. Pressure is the momentum those collisions transfer, so less per second means a lower pressure than PV = nRT predicts. (b) The measured volume is smaller than ideal: attractions draw particles closer together, so at fixed pressure the sample contracts below the ideal volume. (c) Cooling lowers the average kinetic energy while each attraction stays the same strength. Slower particles spend longer within each other's reach, with less energy to pull free, so the same attractions hold them far more effectively. (d) Condensation. Particles with no attractions could never form a liquid, since nothing would hold them together; that real gases condense proves their particles attract.

A3. (a) The free volume is the part of the container available for particle motion once the particles' own volume is removed: free volume = V - nb. (b) The constant b measures the volume excluded per mole, in litres per mole; it measures particle size, so the larger particle gas has the larger b. (c) With less free volume to cross, each particle reaches a wall sooner, so wall collisions are more frequent than the ideal law assumes and transfer more momentum per second: the measured pressure exceeds the ideal prediction. (d) The measured volume is larger than ideal: the particles' own incompressible volume adds to the space the sample needs at fixed pressure.

A4. (a) Z = 1, exactly, by definition of the ideal model. (b) Z < 1 means the measured product PV is smaller than nRT: the sample is more compressible than an ideal gas, and attractions dominate, holding the pressure, or the volume, down. (c) Z > 1 means PV is larger than nRT: the sample resists compression more than an ideal gas, and finite particle volume dominates, as at very high pressures. (d) Z = 1 only says PV happens to equal nRT at that pressure. Attractions pull PV below nRT while particle volume pushes it above, and the two can be equal and cancel there, as measurements either side of that pressure would reveal.

A5. (a) He deviates least, then Ne, then Xe most. All three are nonpolar, with only London dispersion forces, but xenon atoms are larger and their clouds far more polarizable, so their forces are stronger and their own volume larger; helium has the weakest forces and smallest volume. (b)

© 2026 ExamFitter.com · Free AP Chemistry worksheets

NH_3 is polar and hydrogen bonds between its molecules, so neighbours attract far more strongly than methane molecules do. CH_4 is nonpolar, with only weak dispersion forces, so the no forces assumption fails far more badly for NH_3. (c) Gas A, boiling at -196 °C: so low a boiling point certifies very weak attractions. Gas B, condensing at -33 °C, has much stronger attractions, still deflecting its particles at 25 °C. (d) Low pressure and high temperature: low pressure spreads particles apart, making their own volume negligible and keeping them out of each other's reach, and high temperature gives them kinetic energy far larger than any attraction.

B1. (a) P = nRT/V = (1.00 × 0.08206 × 300) ÷ 1.00 = 24.6 atm. (b) Z = PV/nRT = (22.0 × 1.00) ÷ (1.00 × 0.08206 × 300) = 22.0 ÷ 24.6 ≈ 0.894. (c) The measured pressure is below ideal: the shortfall is 2.6 atm, or 2.6 ÷ 24.6 ≈ 0.106, about 11% low. Z below 1 confirms that attractions dominate, pulling particles back from the walls and softening their collisions.

B2. (a) V = nRT/P = (1.00 × 0.08206 × 300) ÷ 200 = 24.6 ÷ 200 ≈ 0.123 L. (b) Z = PV/nRT = (200 × 0.150) ÷ 24.6 = 30.0 ÷ 24.6 ≈ 1.22. (c) The measured volume is above ideal, 0.150 L against 0.123 L, and finite particle volume dominates: at 200 atm the particles are packed so tightly that the volume they occupy, which no pressure can compress away, is a large fraction of the total.

B3. (a) Excluded volume = nb = 3.00 × 0.0427 = 0.128 L. (b) Free volume = V - nb = 2.00 - 0.128 = 1.87 L. (c) Percentage excluded = 0.128 ÷ 2.00 × 100 ≈ 6.40%. (d) Free volume = 0.500 - 0.128 = 0.372 L; percentage excluded = 0.128 ÷ 0.500 × 100 ≈ 25.6%. The excluded volume never changes, but its share of the container quadruples on compression. The negligible volume assumption is safe only while the container is large compared with nb: at low pressures.

B4. (a) Sample X: Z = 9.20 ÷ 10.0 = 0.920. Sample Y: Z = 11.5 ÷ 10.0 = 1.15. (With n, V and T identical in measurement and prediction, Z is measured pressure divided by ideal pressure.) (b) In X attractions dominate (Z < 1); in Y finite particle volume dominates (Z > 1). (c) As a particle of X approaches the wall, the particles behind it pull it backward, so it strikes with less speed and transfers less momentum per second than predicted: 9.20 atm instead of 10.0 atm. (d) Spreading the particles apart makes their own volume a smaller fraction of the container, so the volume effect weakens and Z falls towards 1 from above; attractions may eventually take over and carry Z below 1.

B5. (a) Most ideal first: He, then N_2, then CO_2, then NH_3 least ideal. (b) NH_3 is polar and hydrogen bonds between its molecules, the strongest attraction any of the four can offer, so its pressure and volume fall furthest below ideal. (c) Helium's atoms are the smallest of the four, so their own volume is the most nearly negligible, and its two electrons sit in a small, weakly polarizable cloud, giving the weakest dispersion forces here. (d) Lower the pressure. Spreading the particles out attacks both failures: their own volume becomes a far smaller fraction of the container, and they spend most of their time beyond each other's reach.

B6. (a) Incorrect. Cooling hands attractions their influence: slower particles linger near each other with less energy to escape, so deviation grows on cooling towards the boiling point. (b) Incorrect in

© 2026 ExamFitter.com · Free AP Chemistry worksheets

direction and mechanism. Attractions pull particles together, never apart, and at fixed volume they lower the pressure, pulling particles back from the walls. A pressure above ideal is the signature of finite particle volume. (c) Correct. Attractions dominate at moderate pressures and pull Z below 1, but hard compression packs the particles until their own volume dominates and pushes Z above 1.

C1. (a) Ideal volume = nRT/P = (1.00 × 0.08206 × 300) ÷ 50.0 = 24.6 ÷ 50.0 ≈ 0.492 L. Z = PV/nRT = (50.0 × 0.420) ÷ 24.6 = 21.0 ÷ 24.6 ≈ 0.853. (b) Z = (500 × 0.0600) ÷ 24.6 = 30.0 ÷ 24.6 ≈ 1.22. (c) At 50.0 atm the particles still have appreciable empty space around them, so their own volume is a minor correction, while CO_2 molecules attract each other enough to pull the sample into a smaller volume than ideal: attractions dominate and Z < 1. At 500 atm the particles sit in a tenth of that volume, where the space they occupy is a large fraction of the whole and cannot be squeezed away: particle volume dominates and Z > 1. Only the spacing changed; the temperature and kinetic energy did not. (d) There the two corrections are equal and opposite, so PV matches the ideal value by cancellation. Reporting only it would suggest CO_2 behaves ideally at 300 K, when it deviates clearly on both sides of that pressure.

C2. (a) The constant a corrects the pressure for attractions, which lower it below ideal by an amount growing with their strength. The constant b corrects the volume for finite particle size: the volume available for motion is the container volume minus nb. (b) The prediction fails. The b values show CH_4's particles exclude slightly more volume (0.0428 against 0.0371 L/mol), so on size alone CH_4 would deviate a little more. But a shows NH_3's attractions are far stronger (4.17 against 2.25 $L^2{\cdot}atm{\cdot}mol^{-2}$), because NH_3 is polar and hydrogen bonds while CH_4 is nonpolar. At ordinary pressures attractions are the larger source of deviation, and that outweighs CH_4's small edge in b. (c) NH_3 exerts the lower pressure relative to its ideal prediction: molecules approaching a wall are pulled back more strongly by hydrogen bonding neighbours, striking more softly and less often, and losing more of their ideal pressure than CH_4 loses to weak dispersion forces. (d) A boiling point is where thermal energy just overcomes a liquid's attractions. CH_4 boiling at -161 °C certifies feeble attractions; NH_3 needing -33 °C certifies much stronger ones, still softening its wall collisions at room temperature.

C3. (a) P = nRT/V = (2.00 × 0.08206 × 300) ÷ 5.00 = 49.2 ÷ 5.00 ≈ 9.85 atm. (b) Z = PV/nRT = (9.00 × 5.00) ÷ (2.00 × 0.08206 × 300) = 45.0 ÷ 49.2 ≈ 0.914. (Equivalently, Z is the measured pressure divided by the ideal pressure, 9.00 ÷ 9.85 ≈ 0.914.) (c) The shortfall is 9.85 - 9.00 = 0.85 atm, or 0.85 ÷ 9.85 ≈ 0.086, about 8.6% low. Z below 1 identifies attractions as dominant. (d) NH_3. Helium would sit almost exactly on the ideal prediction: its atoms are tiny, with the weakest dispersion forces of any gas, so neither failure can produce an 8.6% shortfall here. N_2 has only weak dispersion forces and boils at -196 °C, so its deviation would be far smaller. NH_3 is polar, hydrogen bonds, and boils at -33 °C; it alone can pull the pressure this far below ideal. (e) Z rises towards 1: heating raises the average kinetic energy while the attractions stay the same, so they deflect the particles less and the pressure climbs back towards ideal.

© 2026 ExamFitter.com · Free AP Chemistry worksheets

Continue Revising

Topic 3.6 Revision Notes

Topic 3.6 Quiz

Previous Worksheet: Topic 3.5

Next Worksheet: Topic 3.7

Unit 3: All Topics

AP Chemistry Home

© 2026 ExamFitter.com · Free AP Chemistry worksheets