ANSWER KEY.

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3.1 Intermolecular and Interparticle Forces

AP Chemistry | ANSWER KEY

Name specific IMFs (LDF, dipole-dipole, hydrogen bonding, ion-dipole, dipole-induced dipole) and justify with particle-level reasons.

1. When liquid bromine, Br_2, boils, are covalent bonds broken or are intermolecular forces overcome? Explain what the $Br_2(g)$ particles look like.

Intermolecular forces (LDF) are overcome. The Br–Br covalent bond stays intact, so the gas is still made of whole Br_2 molecules, just far apart.

2. Identify <u>all</u> of the intermolecular forces present in a pure sample of each substance.

(a) neon, Ne

(b) carbon dioxide, CO_2

(c) chloromethane, CH_3Cl

(d) ammonia, NH_3

(a) LDF only (b) LDF only (linear, bond dipoles cancel)

(c) LDF and dipole-dipole (polar; every H is on C, so no H-bonding)

(d) LDF, dipole-dipole, and hydrogen bonding (H bonded directly to N)

3. Which of these substances can form hydrogen bonds between their own molecules? Explain each choice.

ethanol (CH_3CH_2OH) dimethyl ether (CH_3OCH_3) hydrazine (N_2H_4) hydrogen sulfide (H_2S)

Ethanol and hydrazine.

Ethanol has H on O. Hydrazine ($H_2N–NH_2$) has H on N, and N has a lone pair. In dimethyl ether every H is on C. In H_2S the H is on S, not N, O, or F.

4. Identify the intermolecular forces between the two different kinds of particles in each mixture.

(a) KBr dissolved in water

(b) I_2 dissolved in hexane, C_6H_{14} (nonpolar)

(c) N_2 gas dissolved in water

(d) acetone (CH_3COCH_3) mixed with water

(a) ion-dipole (b) LDF only (nonpolar + nonpolar)

(c) LDF and dipole-induced dipole (polar + nonpolar)

(d) LDF, dipole-dipole, and hydrogen bonding (water's H to acetone's O)

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5. For each pair, circle the substance with the higher boiling point. Justify your choice in terms of the IMFs involved.

(a) Cl_2 or Br_2

(b) n-pentane (a long chain) or neopentane (compact, ball-shaped). Both are C_5H_{12}.

(c) propane, C_3H_8 (44 g/mol, nonpolar) or acetaldehyde, CH_3CHO (44 g/mol, polar)

(a) Br_2. Both are nonpolar with LDF only. Br_2 has more electrons (70 vs. 34), so it is more polarizable and has stronger LDF.

(b) n-pentane. Same number of electrons, but the long chain has more surface contact with its neighbors, so its LDF is stronger.

(c) acetaldehyde. Similar size means similar LDF, but acetaldehyde is polar and also has dipole-dipole forces.

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6. Which ion, Na^+ or Mg^{2+}, has the stronger ion-dipole attraction to water molecules? Use Coulomb's law to justify your answer. (Mg^{2+} is also the smaller ion.)

Mg^{2+}. By Coulomb's law ($F \propto q_1q_2/r^2$), its larger charge (Mg^{2+} vs. Na^+) and smaller radius (water's δ− O can get closer) both make the attraction stronger.

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7. Water, H_2O, boils at 100 °C. Hydrogen sulfide, H_2S, boils at −60 °C even though H_2S has more electrons. Explain this difference.

Water has hydrogen bonding (H bonded to O, which is very electronegative and small), giving a large δ+ on H and a short distance. H_2S has only LDF and dipole-dipole forces. H_2S has slightly stronger LDF (18 vs. 10 electrons), but for these similar-size molecules, water's hydrogen bonds are much stronger, so more energy is needed to separate water molecules.

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8. Draw one methylamine molecule, CH_3NH_2, and one water molecule showing a hydrogen bond between them. Include lone pairs and label the δ+ and δ− atoms in the hydrogen bond.

Draw $H_3C–NH_2$ (one lone pair on N) and bent H_2O (two lone pairs on O). A dashed line goes from a δ+ H on one molecule to a lone pair on the δ− N or O of the other, close to a straight line. Either direction is correct (water's H to N, or methylamine's N–H to water's O). The H must point at the N or O.

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