

Forces between particles and what they decide

AP Chemistry · Worksheet answers

Check each answer against your own working. For explanations, the key is to name the force, say which substance has more of it and connect that to the property. Numerical answers are given with units and sensible significant figures.

Level: AP Chemistry · **Curriculum:** AP Chem Unit 3

Problem 1 Name the main force

1. Argon is nonpolar: **London dispersion forces**.
2. HCl is polar but H is bonded to Cl, not N, O or F: **dipole-dipole forces**.
3. N-H bonds and a lone pair on N: **hydrogen bonding**.
4. Nonpolar: **London dispersion forces**.

Problem 2 Which can hydrogen bond?

1. **CH₃OH, HF and CH₃NH₂** have H attached to O, F or N and also have a lone pair on that atom.
CH₃OCH₃ has lone pairs on O but no O-H; CH₃F has C-H bonds only.
2. A hydrogen bond needs H bonded to N, O or F in one molecule and a lone pair on N, O or F in a neighbour.

Problem 3 Noble gas boiling points

1. He 4 K, Ne 27 K, Ar 87 K, Kr 120 K.
2. **London dispersion forces**. Down the group each atom has more electrons and a larger, more polarisable cloud, so temporary dipoles are larger and attractions stronger.

Problem 4 Celsius and kelvin

1. $100 + 273.15 = \mathbf{373\ K}$ (373.15 K).
2. $77 - 273.15 = \mathbf{-196\ ^\circ C}$ (-196.15 °C).
3. $78 + 273.15 = \mathbf{351\ K}$ (351.15 K).

Problem 5 Reading a vapour pressure curve

1. About **47 kPa** (accept 45 to 50 kPa).
2. The curve meets 101.3 kPa at about **78 °C**.
3. About **62 °C** (accept 60 to 63 °C).

Problem 6 Why ice floats

1. In ice each molecule hydrogen bonds to four others in an open hexagonal lattice that holds the molecules further apart than the average spacing in liquid water. **The open lattice makes ice less dense.**
2. **Some hydrogen bonds break**, so molecules pack closer; the molecules themselves stay intact.

Problem 7 Viscosity of two liquids

1. Hexane: London dispersion. Diol: **hydrogen bonding** (two O-H groups).
2. Each diol molecule forms several hydrogen bonds with neighbours, so molecules resist sliding past one another. **Stronger IMFs give higher viscosity.**

Problem 8 Pentane and neopentane

1. **London dispersion forces**; both molecules are nonpolar.
2. Neopentane is compact and nearly spherical, so molecules touch at few points and temporary dipoles are small. Pentane is long and chain-like, with more contact area. **Weaker dispersion forces give a lower boiling point.**

Problem 9 Capillary action

1. **Cohesive** forces act between molecules of the liquid; **adhesive** forces act between the liquid and the container wall.
2. Water is attracted to the polar glass surface more strongly than to itself, so adhesion beats cohesion and it rises. Mercury atoms are held by strong metallic bonding, cohesion beats adhesion, and the surface sinks.

Problem 10 Classify the solids

1. **W ionic, X covalent network, Y metallic, Z molecular.**
2. W: high melting point and conducts only when molten or dissolved. X: very high melting point, no conduction, insoluble. Y: conducts as a solid. Z: low melting point, no conduction.

Problem 11 Rank vapour pressures

Propanone > ethanol > water > ethane-1,2-diol.

Propanone has dipole-dipole forces only. Ethanol has one O-H group per molecule and a nonpolar tail. Water has two O-H bonds per molecule in a compact network. The diol has two O-H groups and a heavier molecule, so the strongest attraction and the lowest vapour pressure.

Problem 12 Energy to vaporise ethanol

1. $n = 25.0 / 46.07 = 0.543 \text{ mol}.$

2. $q = 0.5427 \times 38.6 = \mathbf{20.9 \text{ kJ}}$.

Problem 13 Sweat and cooling

1. $n = 150 / 18.02 = 8.324 \text{ mol}$; $q = 8.324 \times 40.7 = \mathbf{339 \text{ kJ}}$.

2. $\Delta T = 339\,000 \text{ J} / (60\,000 \text{ g} \times 3.5 \text{ J/(g}\cdot^\circ\text{C)}) = \mathbf{1.6\ ^\circ\text{C}}$.

Problem 14 Spot the error

1. **Boiling does not break covalent O-H bonds.** It overcomes the intermolecular forces.
2. When water boils, hydrogen bonds between H_2O molecules are overcome so that the molecules separate into vapour; each molecule stays H_2O .

Problem 15 Salt in water and in hexane

1. **Ion-dipole attraction:** the oxygen end (δ^-) of water points to Na^+ , and the hydrogen end (δ^+) points to Cl^- .
2. Hexane is nonpolar and offers only weak dispersion forces, which cannot compensate for the energy needed to separate the ions. **Ion-dipole attractions in water pay that energy; dispersion forces in hexane do not.**

Problem 16 Boiling in Kathmandu

1. Water boils when its vapour pressure equals the external pressure. With lower air pressure, less thermal energy is needed to reach 70.0 kPa.
2. $1/T_2 = 1/373.15 - R \ln(70.0/101.3)/\Delta H = 2.6801 \times 10^{-3} + 7.555 \times 10^{-5} = 2.7556 \times 10^{-3} \text{ K}^{-1}$; $T_2 = 362.9 \text{ K} = \mathbf{89.8\ ^\circ\text{C}}$.

Problem 17 Estimate ΔH of vaporisation

1. $\ln(101.3/8.0) = 2.539$; $1/298.15 - 1/351.55 = 5.095 \times 10^{-4} \text{ K}^{-1}$; $\Delta H = 8.314 \times 2.539 / 5.095 \times 10^{-4} = 41\,430 \text{ J/mol} = \mathbf{41.4 \text{ kJ/mol}}$.
2. The value is about 7 percent high. The equation assumes ΔH constant over the range, but it actually falls as temperature rises, and the 8.0 kPa value is rounded.

Problem 18 Two isomers, two boiling points

1. Propan-1-ol has an O-H bond, so its molecules hydrogen bond to one another; methoxyethane has no H on oxygen and can only use dipole-dipole and dispersion forces. Dispersion forces are about equal because the masses are equal. **Stronger IMFs in propan-1-ol need much more energy to separate molecules.**
2. **Methoxyethane:** weaker forces let more molecules escape at the same temperature.

Problem 19 Hydride trends

1. Boiling point **rises steadily** from CH_4 ($-162\text{ }^\circ\text{C}$) to SnH_4 ($-52\text{ }^\circ\text{C}$) as molecules get larger and dispersion forces strengthen.
2. NH_3 ($-33\text{ }^\circ\text{C}$), H_2O ($100\text{ }^\circ\text{C}$) and HF ($20\text{ }^\circ\text{C}$) are far above the trend of PH_3 , H_2S and HCl . They form hydrogen bonds; the others cannot.
3. Group 14 hydrides such as CH_4 and SiH_4 are nonpolar and have no lone pairs, so **they have only dispersion forces and follow the size trend**.

Problem 20 Design a comparison of IMFs

1. Wrap the bulb in the same amount of cotton wool, wet it with 1.0 mL of the liquid, and record the minimum temperature reached. Control: **starting temperature, volume of liquid, air flow and wick size**.
2. Largest drop for propanone, then ethanol, then water. The weaker the forces, the faster the evaporation and the larger the cooling per second even though water has a larger ΔH_{vap} .
3. Keep flames away and work in a ventilated room, because ethanol and propanone are flammable.