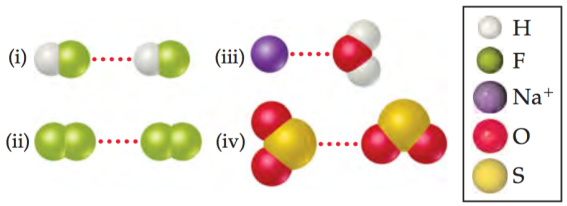
Liquids and Intermolecular Forces
Problem Set

11.2 **(a)** Which kind of intermolecular attractive force is shown in each case here?

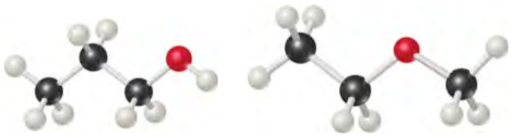


(b) Predict which of the four interactions is

11.3 Do you expect the viscosity of glycerol, C_3H larger or smaller than that of 1-propanol, C_3H

11.4 If 42.0 kJ of heat is added to a 32.0-g sample of liquid methane under 1 atm of pressure at a temperature of −170 °C, what are the final state and temperature of the methane once the system equilibrates? Assume no heat is lost to the surroundings. The normal boiling point of methane is −161.5 °C. The specific heats of liquid and gaseous methane are 3.48 and 2.22 J/g-K, respectively. [Section 11.4]

11.6 The molecules

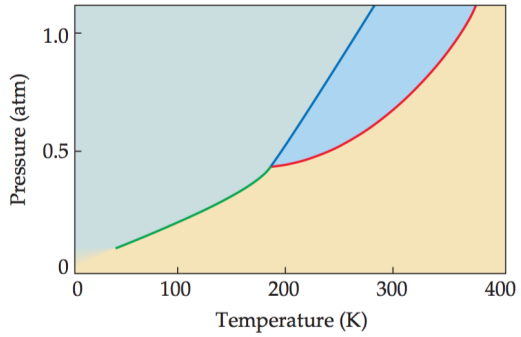


(a) Propanol
97.2 °C

(b) Ethyl methyl ether
10.8 °C

have the same molecular formula (C_3H_8O) but different normal boiling points, as shown. Rationalize the difference in boiling points. [Sections 11.2 and 11.5]

11.7 The phase diagram of a hypothetical substance is



(a) Estimate the normal boiling point and freezing point of the substance.

(b) What is the physical state of the substance under the following conditions: (i) $T = 150$ K, $P = 0.2$ atm, (ii) $T = 100$ K, $P = 0.8$ atm, (iii) $T = 300$ K, $P = 1.0$ atm?

(c) What is the triple point of the substance? [Section 11.6]

11.9 List the three states of matter in order of **(a)** increasing molecular disorder and **(b)** increasing intermolecular attractions. **(c)** Which state of matter is most easily compressed?

11.15 Which type of inte
tween **(a)** all molecu
atom of a polar bo
atom?

11.10 **(a)** How does the average kinetic energy of molecules compare with the average energy of attraction between molecules in solids, liquids, and gases? **(b)** Why does increasing the temperature cause a solid substance to change in succession from a solid to a liquid to a gas? **(c)** What happens to a gas if you put it under extremely high pressure?

11.11 Arrange substances CCl_4, Si, and Ar in order of increasing boiling point.

11.18 Which type of intermolecular force accounts for each of these differences: **(a)** CH_3OH boils at 65 °C; CH_3SH boils at 6 °C. **(b)** Xe is liquid at atmospheric pressure and 120 K, whereas Ar is a gas under the same conditions. **(c)** Kr, atomic weight 84, boils at 120.9 K, whereas Cl_2, molecular weight about 71, boils at 238 K. **(d)** Acetone boils at 56 °C, whereas 2-methylpropane boils at −12 °C.

Acetone

2-Methylpropane

11.19 **(a)** What is meant by the term *polarizability*? **(b)** Which of the following atoms would you expect to be most polarizable: N, P, As, Sb? Explain. **(c)** Put the following molecules in order of increasing polarizability: $GeCl_4$, CH_4, $SiCl_4$, SiH_4, and $GeBr_4$. **(d)** Predict the order of boiling points of the substances in part (c).

11.22 Which member in each pair has the stronger intermolecular dispersion forces: **(a)** Br_2 or O_2, **(b)** $CH_3CH_2CH_2CH_2SH$ or $CH_3CH_2CH_2CH_2CH_2SH$, **(c)** $CH_3CH_2CH_2Cl$ or $(CH_3)_2CHCl$?

11.24 Propyl alcohol ($CH_3CH_2CH_2OH$) and isopropyl alcohol [$(CH_3)_2CHOH$], whose space-filling models are shown, have boiling points of 97.2 °C and 82.5 °C, respectively. Explain why the boiling point of propyl alcohol is higher, even though both have the molecular formula C_3H_8O.

(a) Propyl alcohol (b) Isopropyl alcohol

11.26 Rationalize the difference in boiling points in each pair: **(a)** HF (20 °C) and HCl (−85 °C), **(b)** $CHCl_3$ (61 °C) and $CHBr_3$ (150 °C), **(c)** Br_2 (59 °C) and ICl (97 °C).

11.28 Identify the type or types of intermolecular forces present in each substance and then select the substance in each pair that has the higher boiling point: **(a)** propane C_3H_8 or *n*-butane C_4H_{10}, **(b)** diethyl ether $CH_3CH_2OCH_2CH_3$ or 1-butanol $CH_3CH_2CH_2CH_2OH$, **(c)** sulfur dioxide SO_2 or sulfur trioxide SO_3, **(d)** phosgene Cl_2CO or formaldehyde H_2CO.

11.33 **(a)** Explain why surface tension and viscosity decrease with increasing temperature. **(b)** Why do substances with high surface tensions also tend to have high viscosities?

11.34 (**a**) Distinguish between adhesive forces and cohesive forces. (**b**) What adhesive and cohesive forces are involved when a paper towel absorbs water? (**c**) Explain the cause for the U-shaped meniscus formed when water is in a glass tube.

11.35 Explain the following observations: (**a**) The surface tension of $CHBr_3$ is greater than that of $CHCl_3$. (**b**) As temperature increases, oil flows faster through a narrow tube. (**c**) Raindrops that collect on a waxed automobile hood take on a nearly spherical shape. (**d**) Oil droplets that collect on a waxed automobile hood take on a flat shape.

11.39 Name the phase transition in each of the following situations and indicate whether it is exothermic or endothermic: (**a**) When ice is heated, it turns to water. (**b**) Wet clothes dry on a warm summer day. (**c**) Frost appears on a window on a cold winter day. (**d**) Droplets of water appear on a cold glass of beer.

11.41 Explain why any substance's heat of fusion is generally lower than its heat of vaporization.

11.43 For many years drinking water has been cooled in hot climates by evaporating it from the surfaces of canvas bags or porous clay pots. How many grams of water can be cooled from 35 °C to 20 °C by the evaporation of 60 g of water? (The heat of vaporization of water in this temperature range is 2.4 kJ/g. The specific heat of water is 4.18 J/g-K.)

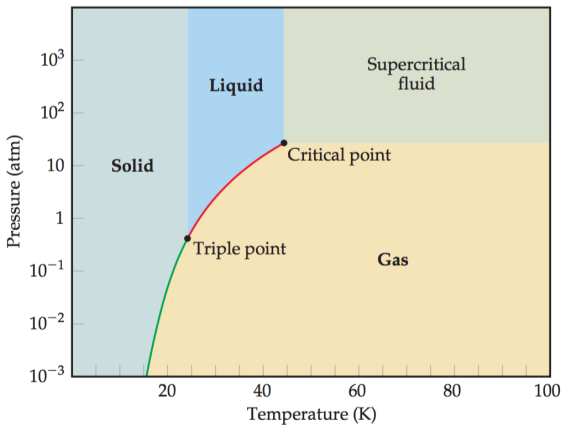
11.46 The fluorocarbon compound $C_2Cl_3F_3$ has a normal boiling point of 47.6 °C. The specific heats of $C_2Cl_3F_3(l)$ and $C_2Cl_3F_3(g)$ are 0.91 J/g-K and 0.67 J/g-K, respectively. The heat of vaporization for the compound is 27.49 kJ/mol. Calculate the heat required to convert 35.0 g of $C_2Cl_3F_3$ from a liquid at 10.00 °C to a gas at 105.00 °C.

11.49 Explain how each of the following affects the vapor pressure of a liquid: (**a**) volume of the liquid, (**b**) surface area, (**c**) intermolecular attractive forces, (**d**) temperature, (**e**) density of the liquid.

11.51 (**a**) Place the following substances in order of increasing volatility: CH_4, CBr_4, CH_2Cl_2, CH_3Cl, $CHBr_3$, and CH_2Br_2. Explain. (**b**) How do the boiling points vary through this series?

11.54 Explain the following observations: (**a**) Water evaporates more quickly on a hot, dry day than on a hot, humid day. (**b**) It takes longer to cook an egg in boiling water at high altitudes than it does at lower altitudes.

11.61 The phase diagram for neon is



Use the phase diagram to answer the following questions. (**a**) What is the approximate value of the normal melting point?

11.57 (**a**) What is the significance of the critical point in a phase diagram? (**b**) Why does the line that separates the gas and liquid phases end at the critical point?
(**b**) Over what pressure range will solid neon sublime? (**c**) At room temperature ($T = 25$ °C) can neon be liquefied by compressing it?