CHAPTER 10 – PRACTICE PROBLEMS

1. Identify the kinds of intermolecular forces that might arise between molecules of each of the following substances: (a) NH₂OH; (b) CBr₄; (c) H₂SeO₄; (d) SO₂; (e) NF₃; (f) PH₃; (g) HI; (h) HIO (O is central atom)

2. Suggest, giving reasons, which substance in each of the following pairs is likely to have the higher normal melting point (Lewis structures may help your arguments): (a) HCl or NaCl; (b) C₂H₅OC₂H₅ (diethyl ether) or C₄H₉OH (butanol); (c) CH₃I or CHF₃; (d) C₂H₄ or CH₃OH; (e) H₂S or H₂O; (f) NH₃ or PH₃; (g) KBr or CH₃Br; (h) CH₄ or SiH₄.

3. Using the VSEPR model, predict the shapes of each of the following molecules and identify the member of each pair with the higher boiling point: (a) PBr₃ or PF₃; (b) SO₂ or CO₂; (c) BF₃ or BCl₃; (d) BF₃ or ClF₃; (e) SF₄ or CF₄

4. In each pair, indicate which substance has the stronger intermolecular forces and explain your reasoning: (a) Ne, Ar; (b) NF₃, BF₃; (c) SiH₄, GeH₄; (d) NaF, HF.

5. Account for the following observations in terms of the type and strength of intermolecular forces. (a) The melting point of solid xenon is −112°C and that of solid argon is −189°C. (b) The vapor pressure of diethyl ether (C₂H₅OC₂H₅) is greater than that of water (c) The boiling point of pentane, CH₃(CH₂)₃CH₃, is 36.1°C, whereas that of 2,2-dimethylpropane (also known as neopentane), C(CH₃)₄, is 9.5°C.

6. Predict which liquid in each of the following pairs has the greater surface tension: (a) cis-dichloroethene or trans-dichloroethene (see structures); (b) benzene at 20°C or benzene at 60°C.

7. Predict which substance in each of the following pairs has the greater viscosity in its liquid form at 0°C: (a) ethanol, CH₃CH₂OH, or dimethyl ether, CH₃OCH₃; (b) butane, C₄H₁₀, or propanone, CH₃COCH₃.

8. Rank the following molecules in order of increasing viscosity at 50°C: C₆H₆SH, C₆H₅OH, C₆H₆.

9. Rank the following liquids in order of increasing viscosity at 25°C: C₆H₆, CH₃CH₂OH, CH₂OHCHOHCH₂OH, CH₂OHCH₂OH, and H₂O. Explain your ordering.
10. The following boiling points correspond to the substances listed. Match the boiling points to the substances by considering the relative strengths of their intermolecular forces.

b.p. (°C): −162, −88.5, 28, 36, 64.5, 78.3, 82.5, 140, 205, 290;
Substance: CH₄, CH₃CHOHCH₃, C₆H₅CH₂OH (has a benzene ring), CH₃CH₃, C₅H₁₀OH (cyclic), (CH₃)₂CHCH₂CH₃, CH₃OH, HOCH₂CHOHCH₂OH, CH₃(CH₂)₃CH₃, CH₃CH₂OH. Hint: The boiling point of (CH₃)₂CHCH₂CH₃ is 28°C and that of CH₃OH is 64.5°C (structures below).

11. The following surface tensions (in millinewtons per meter, mN·m⁻¹, at 20°C) correspond to the liquids listed. Match the surface tension to the substance.

Surface tension: 18.43, 22.75, 27.80, 28.85, 72.75;
Compound: H₂O, CH₃(CH₂)₄CH₃, C₆H₁₀, CH₃CH₂OH, CH₃COOH.

12. Draw the Lewis structure of (a) NI₃; (b) Bi₃; (c) CF₄; (d) SF₄, name the molecular shape, and indicate whether each can participate in dipole–dipole interactions.

13. The molar heat of fusion, ΔH_fus, of Na is 2.6 kJ·mol⁻¹ at its melting point, 97.5°C. How much heat must be absorbed by 5.0 g of solid Na at 97.5°C to melt it?

14. Calculate the amount of heat required to convert 80.0 g of ice at −15.0°C to steam at 125.0°C.

| Specific heat of ice | 2.09 J·g⁻¹·°C⁻¹ |
| Heat of fusion of ice at 0°C | 334 J·g⁻¹ |
| Specific heat of liquid H₂O | 4.184 J·g⁻¹·°C⁻¹ |
| Heat of vaporization of liquid H₂O at 100°C | 2.263 × 10³ J·g⁻¹ |
| Specific heat of steam | 2.03 J·g⁻¹·°C⁻¹ |

15. The normal boiling point of ethanol, C₂H₅OH, is 78.3°C, and its molar heat of vaporization is 39.3 kJ/mol. What would be the vapor pressure, in torr, of ethanol at 50.0°C?
16. Use the following diagram to predict the state of a sample of water under the following conditions: (a) 1 atm, 200.°C; (b) 100. atm, 50.0.°C; (c) 3 torr, 10.0°C.

17. Use the following diagram to predict the state of a sample of CO₂ under the following conditions: (a) 6 atm, –80.°C; (b) 1 atm, –56°C; (c) 80. atm, 25°C; (d) 5.1 atm, –56°C.

18. Using the phase diagram of carbon dioxide, predict what would happen to a sample of carbon dioxide gas at –50°C and 1 atm if its pressure were suddenly increased to 73 atm at constant temperature. What would be the final physical state of the carbon dioxide?
19. The phase diagram for helium is shown here. (a) What is the maximum temperature at which superfluid helium-II can exist? (b) What is the minimum pressure at which solid helium can exist? (c) What is the normal boiling point of helium-I? (d) Can solid helium sublime? (e) Describe the phases in equilibrium at each of helium’s two triple points.

![Helium Phase Diagram](image)

20. The phase diagram for carbon, shown here, indicates the extreme conditions that are needed to form diamonds from graphite. (a) At 2000 K, what is the minimum pressure needed before graphite changes into diamond? (b) What is the minimum temperature at which liquid carbon can exist at pressures below 10 000 atm? (c) At what pressure does graphite melt at 3000 K? (d) Are diamonds stable under normal conditions? If not, why is it that people can wear them without having to keep them under high pressure? (e) Describe the phase transitions that carbon would undergo if compressed at a constant temperature of 2000 K from 100 atm to $1 \times 10^6$ atm; (f) to rank the diamond, graphite, and liquid phases of carbon in order of increasing density.

![Carbon Phase Diagram](image)

21. A new substance developed in a laboratory has the following properties: normal melting point, 83.7°C; normal boiling point, 177°C; triple point, 200. Torr and 38.6°C. (a) Sketch the approximate phase diagram and label the solid, liquid, and gaseous phases and the solid–liquid, liquid–gas, and solid–gas phase boundaries. (b) Sketch an approximate heating curve for a sample at constant pressure, beginning at 500. Torr and 25°C and ending at 200°C.
CHAPTER 10 – PRACTICE PROBLEMS - SOLUTIONS

1. 
   a. Hydrogen bonds
   b. London forces
   c. London forces; dipole-dipole
   d. Dipole-dipole; London forces
   e. Dipole-dipole; London forces
   f. Dipole-dipole; London forces
   g. Dipole-dipole; London forces
   h. Hydrogen bond; London forces

2. 
   a. NaCl - ionic
   b. Butanol - can hydrogen bond
   c. CHF₃ - has stronger dipole-dipole forces
   d. CH₃OH can hydrogen bond
   e. H₂O can hydrogen bond
   f. NH₃ can hydrogen bond
   g. KBr – ionic
   h. SiH₄ has higher London forces

3. 
   a. PBr₃ and PF₃ are both trigonal pyramidal; PBr₃ will have stronger London force
   b. SO₂ is bent (polar); CO₂ is linear (non-polar). SO₂ has dipole-dipole and stronger London force
   c. BF₃ and BCl₃ are both trigonal planar and non-polar; BCl₃ will have stronger London force
   d. BF₃ is trigonal planar; CIF₃ is
   e. SF₄ and CF₄ are both tetrahedral

4. 
   a. Neon and argon will have similar IMF because they are single atoms – not molecules, but the larger element will have the higher MP and BP
   b. NF₃ because it has dipole-dipole forces
   c. GeH₄ due to stronger London forces
   d. NaF because it is ionic

5. 
   a. Xenon is a larger atom and will have higher London forces
   b. Ether is more volatile than water because it can’t hydrogen bond
   c. Pentane is longer and more polarizable than neopentane and will have higher London forces

6. 
   a. The cis-isomer has the chlorine atoms on one “side” of the molecule which makes it more polar than the trans-isomer, which is more symmetric, and less polar; the cis-isomer has larger dipole-dipole forces
   b. As the temperature increases closer to the boiling point, IMF become weaker, and so the warmer liquid will have lower surface tension

7. 
   a. Ethanol will be more viscous
   b. Propanone will be more polar than butane and will have stronger IMF and therefore higher viscosity

8.  C₆H₆ < C₆H₅SH < C₆H₅OH
9. \( \text{C}_6\text{H}_6 < \text{CH}_3\text{CH}_2\text{OH} < \text{H}_2\text{O} < \text{CH}_3\text{OHCH}_2\text{OH} < \text{CH}_3\text{OHCHOHCH}_2\text{OH} \)

10. Here are the numbers:

- **Methane**
  - MW = 16.04
  - bp = -162

- **Isopropanol**
  - MW = 60.10
  - bp = 82.5

- **Benzyl alcohol**
  - MW = 108.14
  - bp = 205

- **Ethane**
  - MW = 30.07
  - bp = -89

- **Cyclopentanol**
  - MW = 86.13
  - bp = 140

- **2-Methylbutane**
  - MW = 72.15
  - bp = 28

- **Ethanol**
  - MW = 46.07
  - bp = 78

11. \( \text{H}_2\text{O} = 72.75; \text{CH}_3\text{COOH} = 28.85; \text{CH}_3\text{CH}_2\text{OH} = 22.75; \text{CH}_3(\text{CH}_2)_4\text{CH}_3 = 18.43; \text{C}_6\text{H}_6 = 28.85 \)
12. 

- Nitrogen triiodide: trigonal pyramidal can participate.
- Boron triiodide: trigonal planar can NOT participate.
- Carbon tetrafluoride: tetrahedral can NOT participate.
- Sulfur tetrafluoride: see-saw can participate.

13. 0.57 kJ
14. $4.70 \times 10^3$ kJ
15. 233 Torr

16. 
   a. Gas
   b. Liquid
   c. Gas

17. 
   a. Solid
   b. Gas
   c. Gas
   d. Gas

18. Deposition would occur, final state would be solid.

19. 
   a. Just over 2 Kelvin
   b. 10 atm
   c. 4 Kelvin
   d. No
   e. Triple point at 1.5 Kelvin: solid, liquid I, liquid II; at 2.2 Kelvin: liquid I, liquid II, gas

20. 
   a. 5-6 GPa
   b. ~4100 K
   c. >25 GPa
d. No. They are constantly decaying to graphite spontaneously. The process is very slow.

e. The graphite would convert to diamond under increasing pressure.