Intermolecular Forces

Types of Solids*	***Intermolecular Force(s) Between Particles***
1. Metallic Crystals (Metals) Examples: Na, Cu, Fe, Mn	*Metallic bonding*: Valence electrons form mobile sea of electrons which comprise the metallic bond.
2. Ionic Crystals (Ionic Solids) Examples: NaCl, $MgCl_2$, MgO	*Ionic Bonding*: Attraction of charged ions for one another. Lattice energy is a measure of ionic bond strength.
3. Covalent Crystals (Network Solids) Examples (small class!): C(diamond), SiC(s), SiO_2 (quartz)	*Network covalent bonding*. Network solids are extremely hard compounds with very high melting and boiling points due to their endless 3-dimensional network of covalent bonds.
4. Molecular Crystals Examples:	One or more of the following:
(a) Need H bonded to O, N or F: H_2O, HF, NH_3.	(a) *Hydrogen bonding*: Hydrogen bonds are weaker than covalent bonds, but stronger than (b) or (c) below.
(b) C_6H_6 (benzene), polyethylene, I_2, F_2, and all the compounds from (a) above.	(b) *Dispersion forces* (induced dipole – induced dipole or London dispersion forces): universal force of attraction between instantaneous dipoles. These forces are weak for small, low-molecular weight molecules, but large for heavy, long, and/or highly *polarizable* molecules. They usually dominate over (c) below.
(c) CHF_3, CH_3COCH_3 (acetone) and H_2O, HF, NH_3.	(c) *Dipole-dipole forces*: these forces act between *polar* molecules. They are much weaker than hydrogen bonding.
Note: ***Van der Waals Forces*** is a category which includes *both* categories (b) and (c) above.	
5. Atomic Crystals Examples: He, Ne, Ar, Kr, Xe	*Dispersion forces*: See Section 4(b) above.

*Note: Many of the compounds given as examples are *not* solids at room temperature. But if you cool them down to a low enough temperature, eventually they will become solids.

Physical properties depend on these forces. The *stronger* the forces between the particles,
(a) the *higher* the *melting point*.
(b) the *higher* the *boiling point*.
(c) the *lower* the *vapor pressure* (partial pressure of vapor in equilibrium with liquid or solid in a closed container at a fixed temperature).
(d) the *higher* the *viscosity* (resistance to flow).
(e) the *greater* the *surface tension* (resistance to an increase in surface area).

1. What *type of crystal* will each of the following substances form in its solid state? Choices to consider are *metallic*, *ionic*, *covalent*, or *molecular* crystals.

(a) C_2H_6 _____ (b) Na_2O _____ (c) SiO_2 _____
(d) CO_2 _____ (e) N_2O_5 _____ (f) $NaNO_3$ _____
(g) Al _____ (h) C(diamond) _____ (I) SO_2 _____

2. Circle ***all*** the compounds in the following list *which would be expected to form intermolecular hydrogen bonds* in the liquid state:

(a) CH_3OCH_3 (dimethyl ether) (b) CH_4 (c) HF (d) CH_3CO_2H (acetic acid) (e) Br_2 (f) CH_3OH (methanol)

3. Specify the *predominant intermolecular force* involved for each substance in the space immediately following the substance. *Then in the last column, indicate which member of the pair you would expect to have the higher boiling point.*

Substance #1	Predominant Intermolecular Force	Substance #2	Predominant Intermolecular Force	Substance with Higher Boiling Point
(a) HCl(g)		I_2		
(b) CH_3F		CH_3OH		
(c) H_2O		H_2S		
(d) SiO_2		SO_2		
(e) Fe		Kr		
(f) CH_3OH		CuO		
(g) NH_3		CH_4		
(h) HCl(g)		NaCl		
(i) SiC		Cu		

Answers:

1. (a) molecular; (b) ionic; (c) covalent (network solid); (d) molecular; (e) molecular; (f) ionic; (g) metallic; (h) covalent (network solid); (i) molecular.

2. Hint: Molecule must contain H bonded to O, N, or F, since only H bonded to O, N, or F can form a hydrogen bond with an O, N, or F on another molecule. Thus (c), (d), and (f) should be circled.

3. Hint: Choices for the predominant intermolecular force are *metallic bonding*, *ionic bonding*, *network covalent bonding*, *hydrogen bonding*, and *dispersion forces (induced dipole – induced dipole forces)*. Dipole-dipole forces are generally dominated by dispersion forces and are rarely predominant.

(a) dispersion forces; dispersion forces; I_2.
(b) dispersion forces; hydrogen bonding; CH_3OH.
(c) hydrogen bonding; dispersion forces; H_2O.
(d) network covalent bonding; dispersion forces; SiO_2.
(e) metallic bonding; dispersion forces; Fe.
(f) hydrogen bonding; ionic bonding; CuO.
(g) hydrogen bonding dispersion forces; NH_3.
(h) dispersion forces; ionic bonding; NaCl.
(i) network covalent bonding; metallic bonding; SiC.