Intermolecular Forces Study Guide - Answers

1. N_2

a) Protons (N) = 7
Neutrons (N) = 7
Electrons (N) = 7

b) N: [He] $2s^2 2p^3$

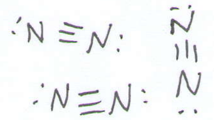
c) :N≡N:

d) EN(N) = EN(N)
ΔEN = 0
No polar bonds

e) No molecular dipole

f) LDF

g) Random organization



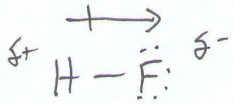
HF

a) Protons (H) = 1 ; Protons (F) = 9
Neutrons (H) = 0 ; Neutrons (F) = 10
Electrons (H) = 1 ; Electrons (F) = 9

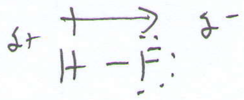
b) H: $1s^1$
F: [He] $2s^2 2p^5$

c) H–F:

d) EN(H) < EN(F)

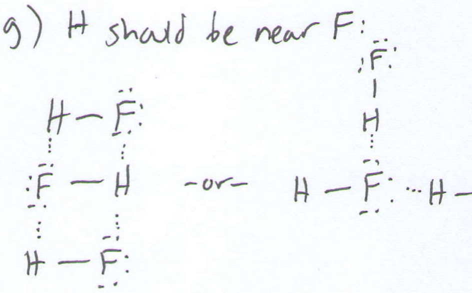


e)



f) HB, DD, LDF

g) H should be near F:



or other answers also acceptable

LiBr

a) Protons (Li^+) = 3 ; Protons (Br^-) = 35
Neutrons (Li^+) = 4 ; Neutrons (Br^-) = 45
Electrons (Li^+) = 2 ; Electrons (Br^-) = 36

b) Li^+: [He] = $1s^2$
Br^-: [Kr] = [Ar] $4s^2 3d^{10} 4p^6$

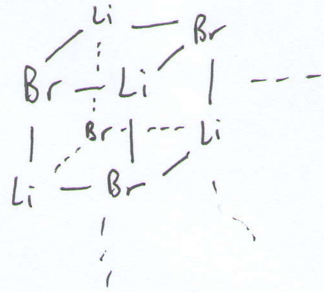
c) $[Li^+][:Br:^-]$

d) Not needed for ionic compounds

e) Not needed for ionic compounds

f) Ionic Bonding

g) Not needed for ionic compounds, but, if you're interested ...



Ne

a) Protons (Ne) = 10

Neutrons (Ne) = 10

Electrons (Ne) = 10

b) Ne: [He] $2s^2 2p^6$

c) Ne or :Ne:

d) No bonds, so no bond dipoles

e) No bond dipoles, so no molecular dipoles

f) LDF

g) Random organization

PH_3

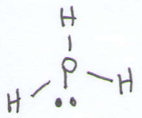
a) Protons (P) = 15

Neutrons (P) = 16

Electrons (P) = 15

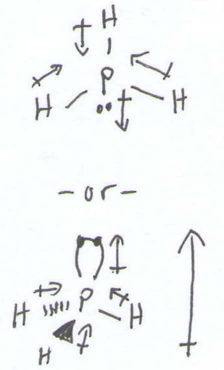
b) P: [Ne] $3s^2 3p^3$

c)



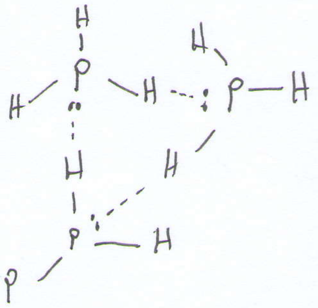
d) EN(P) > EN(H)

e)



f) DD, LDF

g) H should be near P



$CaBr_2$

a) Protons (Ca^{2+}) = 20

Neutrons (Ca^{2+}) = 20

Electrons (Ca^{2+}) = [redacted] 18

b) Ca^{2+}: [Ar] = [Ne] $3s^2 3p^6$

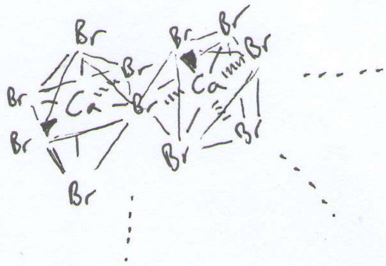
c) [:Br:]$^-$ [Ca^{2+}] [:Br:]$^-$

d) Not needed for ionic compounds

e) Not needed for ionic compounds

f) Ionic Bonding

g) Not needed for ionic compounds, but, if you're interested...



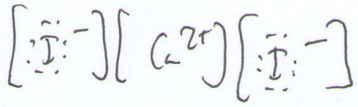
CaI_2

a) Protons (I^-) = 53

Neutrons (I^-) = 74

Electrons (I^-) = 54

b) I^-: $[Xe] = [Kr]5s^2 4d^{10} 5p^6$

c) 

d) Not needed for ionic compounds

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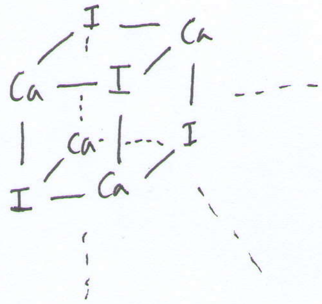
f) Ionic Bonding

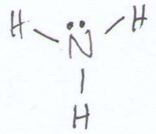
g) Not needed for ionic compounds, but, if you're interested...



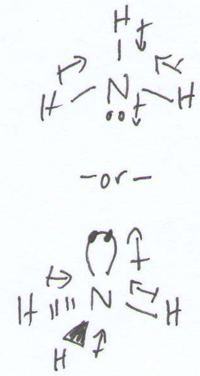
NH_3

a) See previous problems

b) See previous problems

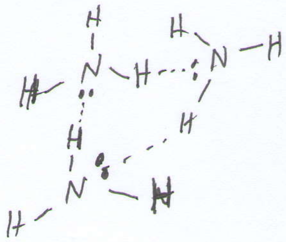
c) 

d) EN(N) > EN(H)

e) 

f) HB, DD, LDF

g) H should be near F



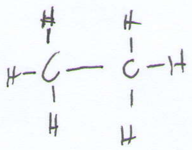
C_2H_6

a) Protons (C) = 6

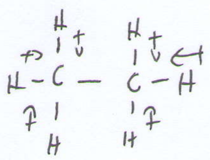
Neutron (C) = 6

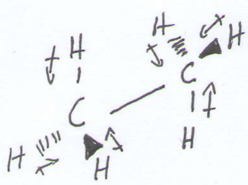
Electrons (C) = 6

b) C: (He) $2s^2 2p^2$

c) 

d) EN(C) > EN(H)

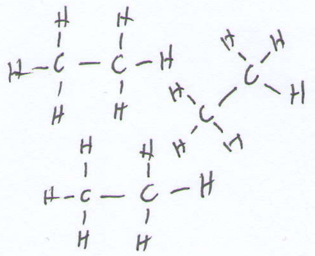


e) 

No molecular dipole

f) LDF

g) Random organization



2. a) From problem (1), we see that N_2, Ne, and C_2H_6 only have London dispersion forces. To compare their boiling points, we need to compare the strength of London dispersion forces in a sample of each.

As the number of electrons in a molecule increases, LDFs increase.

As the size of a molecule increases, LDFs increase.

total $\#e^-(N_2) = 2(7) = 14$; valence $e^- \#(N_2) = 2(5) = 10$

total $\#e^-(Ne) = 1(10) = 10$; valence $e^- \#(Ne) = 1(8) = 8$

total $\#e^-(C_2H_6) = 2(6) + 6(1) = 18$; valence $e^-(C_2H_6) = 2(4) + 6(1) = 14$

So, according to the number of electrons, we have increasing LDFs in the following order: $Ne < N_2 < C_2H_6$

Moreover, the size of a molecule generally increases with the number of atoms in the molecule. So, according to size, LDFs increase in the order: $Ne < N_2 < C_2H_6$.

So, the boiling points increase according to: $Ne < N_2 < C_2H_6$

b) From problem (1), we see that HF and NH_3 have LDFs, DDs, and HBs, but PH_3 only has LDFs and DDs. So the boiling point of PH_3 is lowest, since HBs are stronger intermolecular forces than DDs or LDFs.

Since both HF and NH_3 have the same intermolecular forces and form the same number of hydrogen bonds between individual molecules, we must compare the strength of their hydrogen bonds. This means comparing the magnitude of their bond dipoles:

$EN(H) = 2.1$, $EN(N) = 3.0$, $EN(F) = 4.0$ $\quad \overset{\delta^{++}}{H} \overset{\longrightarrow}{-} \overset{\delta^{--}}{F}$ vs $\overset{\delta^{-}}{N} \overset{\longrightarrow}{-} \overset{\delta^{+}}{H}$

$1.9 = \Delta EN(H-F) > \Delta EN(N-H) = 0.9$

This means that fluorine atoms will be relatively more negatively charged and the hydrogen atoms relatively more positively charged in HF compared to NH_3. This means stronger dipole-dipole interactions between HF molecules than NH_3 molecules, which means a higher boiling point: $PH_3 < NH_3 < HF$

c) Each of these are ionic compounds. To compare the strength of the ionic interactions, we should compare the magnitude of the charges on the ions and the sizes of the ions in each compound:

LiBr	$CaBr_2$	CaI_2
$q_{Li} = +1$, $q_{Br} = -1$	$q_{Ca} = +2$, $q_{Br} = -1$	$q_{Ca} = +2$, $q_I = -1$
$r(Li^+) < r(Ca^{2+})$	$r(Ca^{2+}) > r(Li^+)$	$r(Ca^{2+}) > r(Li^+)$
$r(Br^-) < r(I^-)$	$r(Br^-) < r(I^-)$	$r(I^-) > r(Br^-)$
$F_{LiBr} = \frac{k q_{Li} q_{Br}}{r_{LiBr}^2}$	$F_{CaBr} = \frac{k q_{Ca} q_{Br}}{r_{CaBr}^2}$	$F_{CaI} = \frac{k q_{Ca} q_I}{r_{CaI}^2}$
$F_{LiBr} = \frac{-k}{r_{LiBr}^2}$	$F_{CaBr} = \frac{-2k}{r_{CaBr}^2}$	$F_{CaI} = \frac{-2k}{r_{CaI}^2}$

* Important, as F ↓, attraction ↑, boiling point ↑ *

From above, we see that $r_{LiBr} < r_{CaBr} < r_{CaI}$. Based on this, we see that

$$\frac{-2k}{r_{CaBr}^2} < \frac{-2k}{r_{CaI}^2}$$

$$F_{CaBr} < F_{CaI}$$

$$\text{boiling point}(CaBr_2) > \text{boiling point}(CaI_2)$$

The comparison between LiBr and $CaBr_2$ is more difficult. However, the distance between Li and Br ions and the distance between Ca and Br are not very different, so the greater charges on the ions in $CaBr_2$ is more important than the interionic distances. So, the order of these elements, in terms of increasing boiling points, is:

$$CaI_2 < LiBr < CaBr_2$$

d) First, let's list the intermolecular forces present in a sample of each of the compounds:

N_2 – LDF

PH_3 – LDF, DD

CaI_2 – Ionic Bonding

Since the strength of forces increases according to ionic bonding > HB > DD > LDF, we rank the following compounds as $CaI_2 > PH_3 > N_2$.

e) Following the same analysis as in (d), we see that

C_2H_6 – LDF

HF – HB, DD, LDF $\Rightarrow$ $LiBr > HF > C_2H_6$

LiBr – Ionic Bonding

f) Combining our answers from (a)-(e), we have

$$\underbrace{(N_2, Ne, C_2H_6)}_{\text{LDF only}} < \underbrace{PH_3}_{\text{LDF, DD}} < \underbrace{(HF, NH_3)}_{\text{LDF, DD, HB}} < \underbrace{(LiBr, CaBr_2, CaI_2)}_{\text{Ionic Bonding}}$$

$$\downarrow$$

$$Ne < N_2 < C_2H_6 < PH_3 < NH_3 < HF < CaI_2 < LiBr < CaBr_2$$

Boiling Points:	27K	77K	184.6 K	185 K	240K	293K	1373K	1538K	2208K