AP® Chemistry (Operational)
2004 Sample Student Responses

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Answer EITHER Question 7 below OR Question 8 printed on page 26. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 15 percent.

7. Use appropriate chemical principles to account for each of the following observations. In each part, your response must include specific information about both substances.

   (a) At 25°C and 1 atm, F_2 is a gas, whereas I_2 is a solid.

   (b) The melting point of NaF is 993°C, whereas the melting point of CsCl is 645°C.

   (c) The shape of the ICl_4^- ion is square planar, whereas the shape of the BF_4^- ion is tetrahedral.

   (d) Ammonia, NH_3, is very soluble in water, whereas phosphine, PH_3, is only moderately soluble in water.

a F_2 and I_2 are both non polar molecules. The only forces between the molecules are London dispersion forces. These forces are created by the attraction of temporary dipoles. Molecules with more total electrons can form stronger dipoles, so the forces are stronger. An I_2 molecule has almost 6 times as many total electrons as a F_2 molecule. The forces between I_2 molecules are much stronger than those between F_2 molecules. At 25°C F_2 molecules have enough energy to overcome these forces, so they form a gas, but I_2 molecules cannot overcome the forces so they form a solid

b The equation for lattice energy (Coulomb's law) is $E = k\frac{q_1 q_2}{r}$

In both NaF and CsCl, both charges are 1, but the atoms of Cs and Cl are farther apart than the atoms of Na and F. The larger distance means it takes less energy to separate the Cs and Cl ions, so CsCl melts at a lower temperature. Cs has a larger atomic radius than

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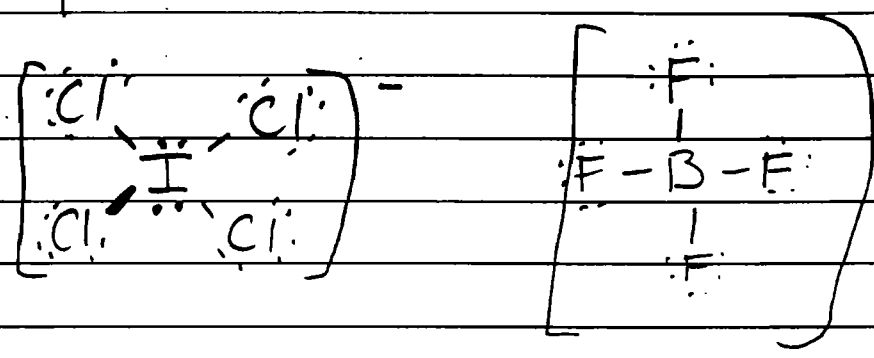
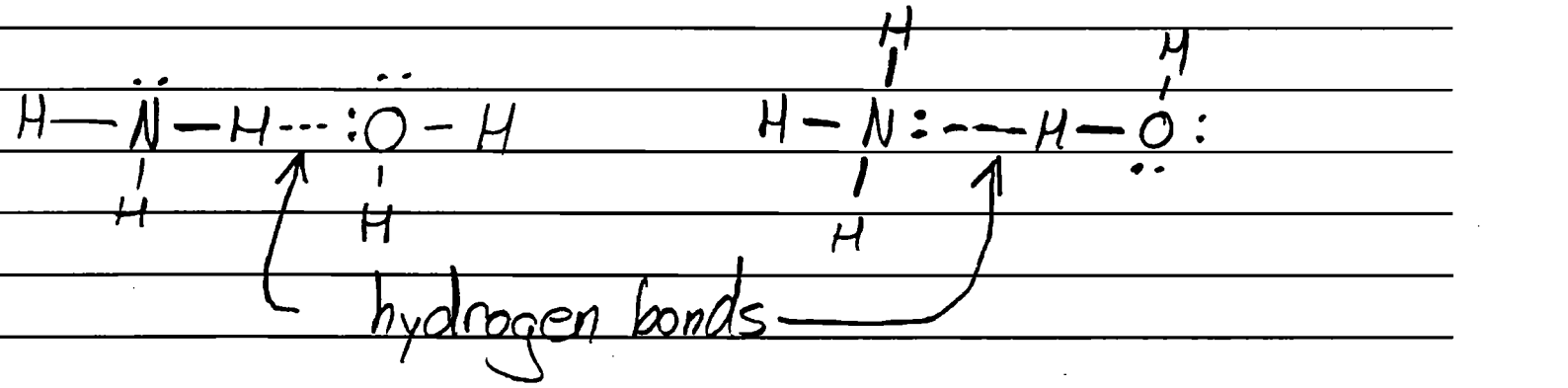
Na, and Cl has a larger atomic radius than F because Cs and Cl have more filled electron shells than Na and F

c 

I in ICl_4^- has six total e⁻ clouds surrounding it. Two of these are unshared pairs. The clouds arrange themselves in an octahedral geometry, and the two unshared pairs, which take up more room than bonds, take up opposite corners, leaving the 4 Cl in a square

B in BF_4^- has only four total e⁻ clouds around it and no unshared pairs. The clouds spread out in a tetrahedral geometry

d NH_3 and PH_3 are both polar. However, only NH_3 can form hydrogen bonds with water molecules. This makes it much more soluble in water. The bonds in PH_3 are less polar, and P is too large to hydrogen bond.



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B B B B B B B B B B B B B 7B,

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a) F_2 is a gas at this temperature and pressure because it has few intermolecular forces. I_2, however has a much greater molecular mass, about sixty times greater, so its molecules have very large dispersion forces between them, whereas F_2 has very little at all.

b) NaF has stronger forces between its ions than does CsCl, because Na^+ and F^- have smaller atomic radii than Cs^+ and Cl^-, which means Na^+ and F^- are closer together in the molecule and more strongly attracted to each other. Also, Cs^+ and Cl^- have more electrons and greater atomic radii, which causes a greater distance and weaker attraction between the two than in NaF.

c) This is a matter of number of valence electrons that causes this difference.
ICl^- valence $e^- = 7 + 4(7) + 1 = 36$
BF_4^- valence $e^- = 3 + 4(7) + 1 = 32$
In ICl, 3 electron pairs surround each

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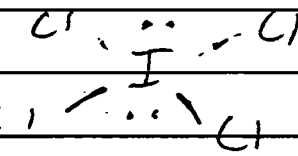
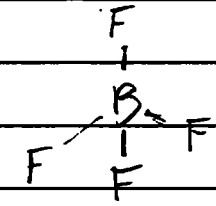
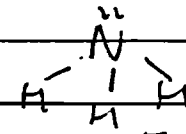
Cl atom, and each Cl atom is bonded to the I atom. This accounts for (3·4)·(2) electrons in free Cl pairs, 24, and 4(2) electrons shared between the I and Cl's, or 8. This totals 32, however 2 electron pairs are left, which surround the I atom and give it an extended octet. The ICl^- is therefore square planar



The BF_4^- atom is almost identical to ICl_4^-, except that it only has 32 electrons. This results in filled octets that total 32, so no extra pairs of electrons surround B. Therefore BF_4^- is tetrahedral.



d) Only polar substances dissolve in water, because water is a polar substance, therefore, a more polar substance will dissolve better. NH_3 is rather polar because it has 8 valence electrons and has bent geometry,  it is very polar with an electron pair on the N. PH_3 ~~may~~ is similar, with 8 valence e^-, however because it is a larger atom, its extra electron pair (on P) has less of an effect than on N for its ~~p~~polarity simply due to the size of a Phosphorus atom.

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@ Since they are both held together by London dispersion forces, they must be judged on the basis of molar mass. Since I_2 has a much higher molar mass, the forces holding the I_2 molecule together is much stronger than for F_2 which has weakly attracted forces that allow it to roam free as a gas. I_2 since it has stronger intermolecular forces, is held together strong as a solid

ⓑ The polar bond between NaF is much stronger than it is for CsCl. since F is the most electronegative element, it will create a very polar bond. The more polar the bond, the harder it is to break the forces holding that bond together. The more force required to break the bond, the higher the boiling point will be. The Cs-Cl bond, although polar, is not as strongly held together as the Na-F bond, thus the boiling point will be significantly less.

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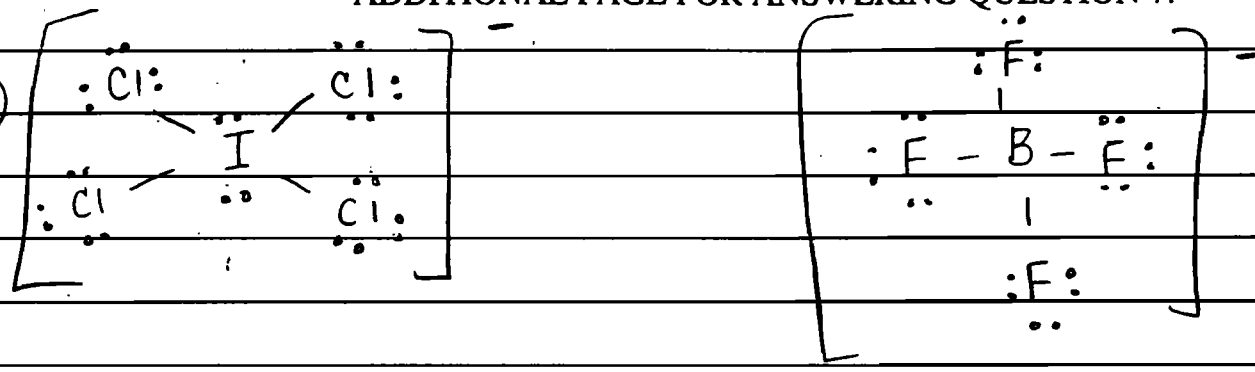
© 

Since I is capable of having an expanded shell, the I violates the octet rule. Since originally has 7 electrons, it accepts the extra electron (that gives the entire molecule a negative charge) to fill up the 8 electrons. Thus making it have 4 single bonds with Cl and 2 sets of lone pairs. (This characterizes a square planar configuration.) BF_4^- on the other hand has only 3 valence electrons available for bonding. When the extra electron is added on however, this allows the B to bond (single) with the fourth F atom, thus creating a total of 4 single bonds (which characterizes the tetrahedral shape)

@ NH_3 is very soluble in water because it has hydrogen bonding (N-H, O-H, F-H) The N-H (polar) bond will be very attracted to the polar water molecules, which also have hydrogen-bonding. PH_3 on the other hand, does not have hydrogen bonding. (Since like dissolves like, the nonpolar H-P bond will not be attracted to the polar water molecules.

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