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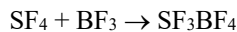
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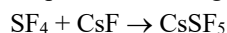
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[1] Answer the following questions about the structures of ions that contain only sulfur and fluorine.

(a) The compounds SF₄ and BF₃ react to form an ionic compound according to the following equation.



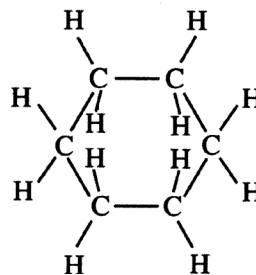
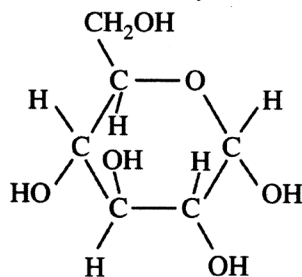
- Draw a complete Lewis structure for the SF₃⁺ cation in SF₃BF₄.
 - Identify the type of hybridization exhibited by sulfur in the SF₃⁺ cation.
 - Identify the geometry of the SF₃⁺ cation that is consistent with the Lewis structure drawn in part (a)(i).
 - Predict whether the F—S—F bond angle in the SF₃⁺ cation is larger than, equal to, or smaller than 109.50°. Justify your answer.
- (b) The compounds SF₄ and CsF react to form an ionic compound according to the following equation.



- Draw a complete Lewis structure for the SF₅⁻ anion in CsSF₅.
- Identify the type of hybridization exhibited by sulfur in the SF₅⁻ anion.
- Identify the geometry of the SF₅⁻ anion that is consistent with the Lewis structure drawn in part (b)(i).
- Identify the oxidation number of sulfur in the compound CsSF₅.

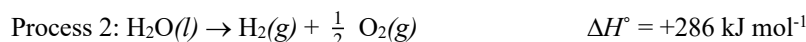
[2] Answer each of the following in terms of principles of molecular behavior and chemical concepts.

(a) The structures for glucose, C₆H₁₂O₆, and cyclohexane, C₆H₁₂, are shown below.



Identify the type(s) of intermolecular attractive forces in

- pure glucose
 - pure cyclohexane
- (b) Glucose is soluble in water but cyclohexane is not soluble in water. Explain.
- (c) Consider the two processes represented below.



- For each of the two processes, identify the type(s) of intermolecular or intramolecular attractive forces that must be overcome for the process to occur.
- Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

When water boils, H₂O molecules break apart to form hydrogen molecules and oxygen molecules.

(d) Consider the four reaction-energy profile diagrams shown below.

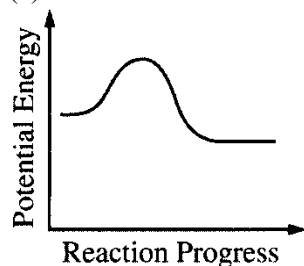


Diagram 1

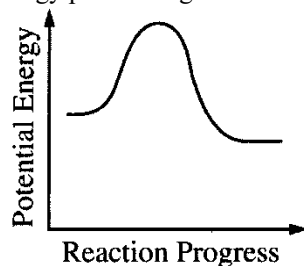


Diagram 2

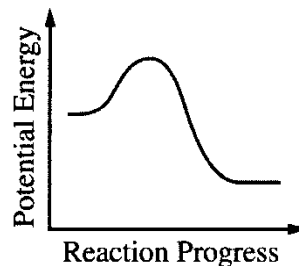


Diagram 3

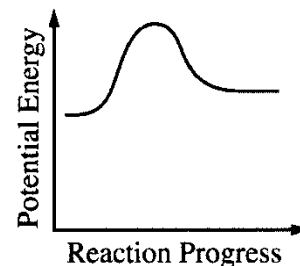


Diagram 4

- (i) Identify the two diagrams that could represent a catalyzed and an uncatalyzed reaction pathway for the same reaction. Indicate which of the two diagrams represents the catalyzed reaction pathway for the reaction.
- (ii) Indicate whether you agree or disagree with the statement in the box below. Support your answer with a short explanation.

[3] Use principles of atomic structure, bonding and/or intermolecular forces to respond to each of the following. Your responses must include specific information about all substances referred to in each question.

- (a) At a pressure of 1 atm, the boiling point of $\text{NH}_3(l)$ is 240 K, whereas the boiling point of $\text{NF}_3(l)$ is 144 K.
 - (i) Identify the intermolecular forces(s) in each substance.
 - (ii) Account for the difference in the boiling points of the substances.
- (b) The melting point of $\text{KCl}(s)$ is 776°C , whereas the melting point of $\text{NaCl}(s)$ is 801°C .
 - (i) Identify the type of bonding in each substance.
 - (ii) Account for the difference in the melting points of the substances.
- (c) As shown in the table below, the first ionization energies of Si, P, and Cl show a trend.

Element	First Ionization Energy (kJ mol^{-1})
Si	786
P	1012
Cl	1251

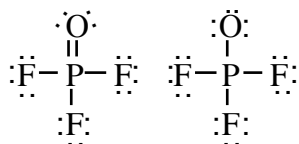
- (i) For each of the three elements, identify the quantum level (e.g., $n=1$, $n=2$, etc.) of the valence electrons in the atom.
- (ii) Explain the reasons for the trend in the first ionization energy.
- (d) A certain element has two stable isotopes. The mass of one of the isotopes is 62.93 amu and the mass of the other isotope is 64.93 amu.
 - (i) Identify the element. Justify your answer.
 - (ii) Which isotope is more abundant? Justify your answer.

[4] Answer the following questions that relate to chemical bonding

- (a) In the boxes provided, draw the complete Lewis structure (electron-dot diagram) for each of the three molecules represented below.

CF ₄	PF ₅	SF ₄
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- (b) On the basis of the Lewis structures drawn above, answer the following questions about the particular molecule indicated.
 - (i) What is the F-C-F bond angle in CF_4 ?
 - (ii) What is the hybridization of the valence orbitals of P in PF_5 ?
 - (iii) What is the geometric shape formed by the atoms in SF_4 ?
- (c) Two Lewis structures can be drawn for the OPF_3 molecule, as shown below.



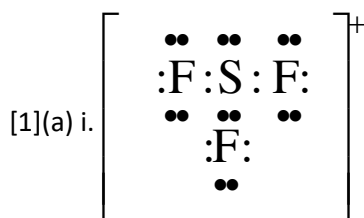
Structure 1 Structure 2

- (i) How many sigma bonds and how many pi bonds are in structure 1?
- (ii) Which one of the two structures best represents a molecule of OPF_3 ? Justify your answer in terms of formal charge.

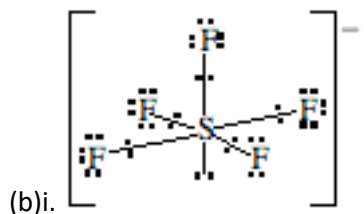
[5] Use appropriate chemical principles to account for each of the following observations. In each part, your response must include specific information about both substances.

- (a) At 25° C and 1 atm, F₂ is a gas whereas I₂ is a solid.
- (b) The melting point of NaF is 993° C, whereas the melting point of CsCl is 645°.
- (c) The shape of ICl₄⁻ ion is square planar, whereas the shape of BF₄⁻ ion is tetrahedral.
- (d) Ammonia, NH₃, is very soluble in water, whereas phosphine, PH₃, is only moderately soluble in water.

ANSWERS



- (ii) sp^3 .
- (iii) pyramidal
- (iv) smaller than 109.50° . The lone pair of unbonded electrons occupies more space than the bonded pairs and, therefore, pushed the bonded pairs away and hence, a smaller bond angle than a perfect tetrahedron.



- (ii) sp^3d^2
- (iii) square pyrimidal
- (iv) $S = +4$

[2]

(a)

	London dispersion forces	polar attractions	hydrogen bonding
(i) pure glucose	+	+	+
(ii) pure cyclohexane	+	-	-

(b) The hydroxyl groups ($-OH$) in glucose create polar regions on the molecule, these polar regions can be attracted to the polar water molecules, allowing it to dissolve. Cyclohexane has not such structures and is non-polar and non-water soluble. Like dissolves like.

(c)i.

	Intermolecular forces			Intramolecular forces
	London dispersion forces	polar attractions	hydrogen bonding	H–O covalent bond
process 1	+	+	+	-
process 2	+	+	+	+

(ii) disagree; there is not enough energy in boiling water (373 K) to break a H–O covalent bond.

(d) (i) diagrams 1 & 2; diagram 1 represents the catalyzed reaction pathway

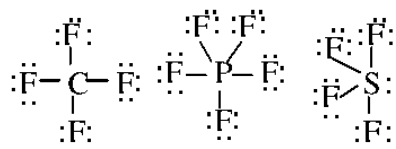
(ii) disagree; a catalyst does not increase the temperature and, therefore, does not increase the amount of energy present in the mixture. It only provides a lower energy pathway (i.e., smaller activation energy requirement) for the reaction to occur.

[3] (i)

force	NH_3	NF_3
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London dispersion	+	+
polar attraction	+	+
hydrogen bonding	+	-
ionic attraction	-	-

- (ii) the ability of ammonia to create intermolecular hydrogen bonds, leads to higher amount of energy to separate the molecules by boiling them.
- (b) (i) both compounds have ionic bonding
(ii) the sodium ion in NaCl is a smaller size than the corresponding potassium ion in KCl. This smaller size creates a larger charge density and greater ion Coulombic attraction in the NaCl, making it harder to melt.
- (c) (i) Si, $n = 3$; P, $n = 3$; Cl, $n = 3$
(ii) in terms of atomic radius, $\text{Si} > \text{P} > \text{Cl}$ and nuclear charge $\text{Cl} > \text{P} > \text{Si}$, the smaller and higher charged chlorine atom has the greatest attraction for its electrons than the other two. This means that it takes more energy to remove an electron from chlorine than the other two. The opposite is true for silicon and it should have the smallest value.
- (d) (i) copper; since the atomic mass of an element is the weighted average of its natural isotopes, then the atomic mass of the element must be between 62.93 and 64.94.
(ii) 62.93; the isotope that is closer to the atom mass of the element is more abundant of the two ($63.546 - 62.93 = 0.616$; $64.94 - 63.546 = 1.384$)



[4] (a)

- (b) (i) 109.5°
(ii) sp^3d
(iii) see-saw
- (c) (i) 4 sigma, 1 pi
(ii) structure 1;
In structure 1, oxygen has a formal charge of 0 (6 valence electrons – 6 assigned electrons), each fluorine is 0 (7 valence electrons – 7 assigned electrons), phosphorus is 0 (5 valence electrons – 5 assigned electrons),
In structure 2, oxygen has a formal charge of –1 (6 valence electrons – 7 assigned electrons), each fluorine is 0 (7 valence electrons – 7 assigned electrons), phosphorus is +1 (5 valence electrons – 4 assigned electrons)
According to the electroneutrality rule, the better Lewis structure is the one with the smallest separation of formal charge, *i.e.*, structure 1.

[5]

- (a) F_2 is a smaller & lighter molecule than I_2 , at the same temperature F_2 , on average is faster than I_2 . The I_2 molecule has 106 electrons to the 18 of the F_2 and, therefore, exhibits a greater vander Waal attraction.
- (b) each ion in NaF has a smaller size than the corresponding ion in CsCl. This smaller size creates a larger charge density and greater ion Coulombic attraction in the NaF, making it harder to melt.
- (c) The ICl_4^- ion contains the sp^3d^2 hybridization due to the expanded octet around the central iodine. The chlorides are equatorially bonded in a square around the iodine with the extra pairs of electrons along the axis. The BF_4^- ion has sp^3 hybridization which characteristically has the tetrahedral shape.
- (d) ammonia is a more polar molecule than phosphine and can make hydrogen bonds with the solvent, water. This creates a greater solute-solvent attraction and greater solubility.