Question No. 1 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 1. Which of the following statements is ***incorrect***?

(A) Carbon can form a maximum of 4 bonds.
(B) Phosphorus can form at least 3 bonds.
(C) Oxygen can form at least 2 bonds.
(D) Nitrogen can form 3 or 4 bonds.
(E) Fluorine can form a maximum of 3 bonds.

Feedback

A. Incorrect!
The statement "Carbon can form a maximum of 4 bonds." is correct. A single carbon atom is capable of making a maximum of 4 bonds though certain reactive species (like carbanions, carbocations, and radicals) may have less than 4 bonds. Looking at the remaining answers, can you determine anything about their bonding by their position on the periodic table?

B. Incorrect!
The statement "Phosphorus can form at least 3 bonds." is correct. Phosphorus, which falls under nitrogen in the periodic table, can, like nitrogen, form at least 3 bonds. It can form up to 5 bonds since, as a third period element, it has more electrons. Looking at the remaining answers, can you determine anything about their bonding by their position on the periodic table?

C. Incorrect!
The statement "Oxygen can form at least 2 bonds." is correct. Oxygen will form two bonds to fill its valence shell. It can, under special circumstances, form three bonds as it does in the hydronium ion (H_3O^+). Looking at the remaining answers, can you determine anything about their bonding by their position on the periodic table?

D. Incorrect!
The statement "Nitrogen can form 3 or 4 bonds" is correct. Nitrogen normally forms three bonds to fill its valence shell. It can, under specific circumstances, donate its lone pair to form a fourth bond.

E. Correct!
Fluorine is not capable of forming three bonds. Located in the column to the immediate left of the noble gases, fluorine typically forms one bond to fill its octet.

Solution

(1) Determine the location of the atoms listed in the statements above on the periodic table.

(2) Determine the number of electrons each atom needs to fill its octet/valence shell.

Carbon has 4 valence electrons and needs 4 more to have a full octet. Therefore it can form up to 4 covalent bonds to obtain these electrons.

Phosphorus has 5 valence electrons and needs 3 more to have a full octet. Therefore it can form covalent bonds with three other atoms to obtain these electrons.

Oxygen has 6 valence electrons and needs 2 more to have a full octet. Therefore it can form covalent bonds with two other atoms to obtain these electrons.

Nitrogen has 5 valence electrons and needs 3 more to have a full octet. Therefore, it can form covalent bonds with three other atoms to obtain these electrons. In some circumstances, it can donate its lone pair for form a fourth bond to another atom.

Fluorine has 7 valence electrons and needs 1 more to have a full octet. It only has to form one bond to obtain this electron.

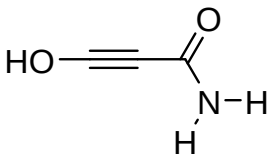
Therefore, the correct answer is (E).

Question No. 2 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 2. Identify all the functional groups in the following structure:



(A) Ether, alkene, ketone, amine
(B) Alcohol, alkyne, amide
(C) Thiol, alkyne, amide
(D) Amine, aldehyde, alkyne, alcohol
(E) Amine, ether, alkene

Feedback

A. Incorrect!
The above structure does not contain an ether, an alkene, a ketone or an amine. Look at the structure. Start multiple bonds between two carbons. Then look for heteroatoms (atoms besides carbon and hydrogen like N, P, S, and O). Review the functional groups that contain the heteroatoms you find in the molecule.

B. Correct!
The above structure contains three functional groups: an alcohol (R-OH), an alkyne (carbon-carbon triple bond), and an amide ($R\text{-}(C{=}O)NH_2$).

C. Incorrect!
While the above structure does contain an alkyne and an amide, it does not contain a thiol. Go back and review the different oxygen containing functional groups.

D. Incorrect!
While the above structure does contain an alcohol and an alkyne, it does not contain an amine and an aldehyde. Go back and review the different carbonyl (C=O) containing functional groups.

E. Incorrect!
This structure does not contain an amine, ether or alkene. Go back and review the different organic functional groups.

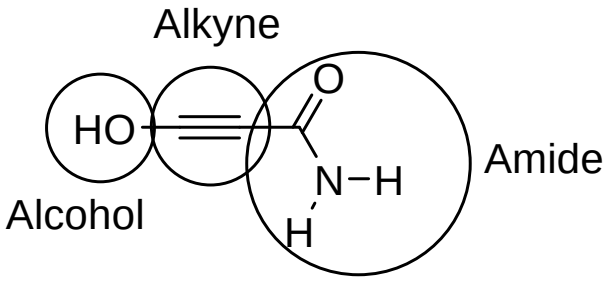
Solution

(1) Look at the given structure. Determine the following:

(a) Does the structure contain only carbon and hydrogen atoms and only single bonds? If yes, the molecule is an alkane. If no, go to (b).
(b) Look for carbon-carbon double and triple bonds or an aromatic ring. Circle each one you find. Write the functional group's name (alkene, alkyne, aromatic) next to it.

(2) Does the structure contain any heteroatoms (atoms other than carbon or hydrogen)? If so, which ones? Circle each one you find and write the functional group's name next to it.

If a halogen (F, Cl, Br, I) is present, consider an alkyl halide. If sulfur is present, consider a thiol or sulfide. If a nitrogen is present, consider an amine or a nitrile. If a carbonyl (C=O) is present, then several options must be considered: aldehyde, ketone, acid halide, ester, carboxylic acid, anhydride, or amide.



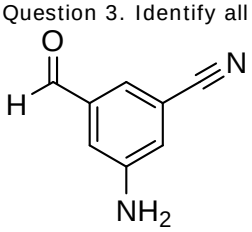
Therefore, the correct answer is (B).

Question No. 3 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 3. Identify all of the functional groups in the following structure:



(A) Ester, carboxylic acid, amine, aromatic
(B) Ketone, aromatic, alkyne, amine
(C) Ketone, amine, aromatic, nitrile
(D) Aromatic, amine, nitrile, aldehyde
(E) Aromatic, nitrile, ester, amine

Feedback

A. Incorrect!
While the structure above does contain an aromatic ring and an amine, it does not contain an ester or a carboxylic acid. Go back and review carbonyl (C=O) containing functional groups and nitrogen containing functional groups.

B. Incorrect!
While the structure above does contain an aromatic ring and an amine, it does not contain a ketone or an alkyne. Go back and review the carbonyl (C=O) containing functional groups and the nitrogen containing functional groups.

C. Incorrect!
While the structure above does contain an aromatic ring, an amine and a nitrile, it does not contain a ketone. Go back and review the carbonyl (C=O) containing functional groups.

D. Correct!
The structure above contains four functional groups: an aromatic ring (six membered ring with alternating single and double bonds), an amine (R-NH_2), a nitrile (carbon-nitrogen triple bonded together), and an aldehyde (R-(C=O)H).

E. Incorrect!
While the structure contains an aromatic ring, an amine group, and a nitrile group, it does not have an ester group. Go back and review the carbonyl (C=O) containing functional groups.

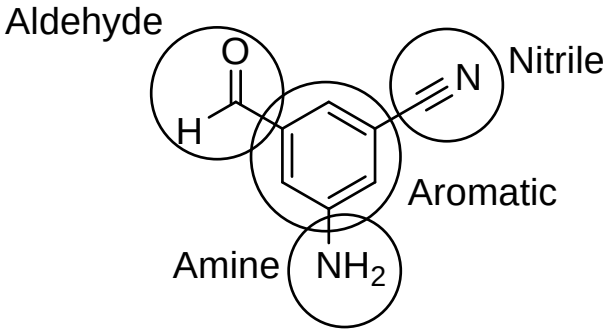
Solution

(1) Look at the given structure. Determine the following:

(a) Does the structure contain only carbon and hydrogen atoms and only single bonds? If yes, the molecule is an alkane. If no, go to (b).
(b) Look for carbon-carbon double and triple bonds or an aromatic ring. Circle each one you find. Write the functional group's name (alkene, alkyne, aromatic) next to it.

(2) Does the structure contain any heteroatoms (atoms other than carbon or hydrogen)? If so, which ones? Circle each one you find and write the functional group's name next to it.

If a halogen (F, Cl, Br, I) is present, consider an alkyl halide. If sulfur is present, consider a thiol or sulfide. If a nitrogen is present, consider an amine or a nitrile. If a carbonyl (C=O) is present, then several options must be considered: aldehyde, ketone, acid halide, ester, carboxylic acid, anhydride, or amide.



Therefore, the correct answer is (D).

Question No. 4 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 4. Which statement below is ***correct***?

(A) A carboxylic acid contains a H attached to the carbon of a carbonyl (C=O) with a H or R attached to the other side of the carbon [H(C=O)-].
(B) An acid halide contains a halogen (where X = F. Cl, Br, or I) attached to the carbon of a carbonyl (C=O) with a H or R attached on the other side of the carbon [-(C=O)X].
(C) An ester contains an H or R attached to a carbonyl (C=O) with an –OH on the other side of the carbon [-(C=O)OH].
(D) A ketone contains two carbonyls (C=O) separated by an oxygen (O) with an R or H attached to the other side of each carbon [-(C=O)O(C=O)-].
(E) An aldehyde contains an H or R attached to a carbonyl (C=O) with an –OR on the other side of the carbon [-(C=O)OR].

Feedback

A. Incorrect!
A carboxylic acid contains an H or R attached to a carbonyl (C=O) with an –OH on the other side of the carbon [-(C=O)OH]. The functional group described in (A) is an aldehyde.

B. Correct!
An acid halide contains a halogen (abbreviated with X) that is attached to the carbon of a carbonyl group (C=O). An alkyl group (R) or a hydrogen (H) can be attached to the other side of the carbonyl carbon.

C. Incorrect!
An ester contains an H or R attached to a carbonyl (C=O) with an –OR on the other side of the carbonyl carbon [-(C=O)OR]. The functional group described in (C) is a carboxylic acid.

D. Incorrect!
A ketone contains two R groups attached to the carbon of a carbonyl (C=O) [R(C=O)R]. The functional group described in (D) is an anhydride.

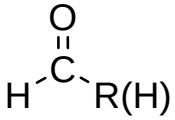
E. Incorrect!
An aldehyde contains a H attached to the carbon of a carbonyl (C=O) with a H or R attached to the other side of the carbon [H(C=O)-]. The functional group described in (E) is an ester.

Solution

(1) Determine exactly what functional group each statement is describing.

Since it can be a little confusing to read a description of a functional group, it is best to draw the structure of what is being described.

For instance, (A) states "A carboxylic acid contains a H attached to the carbon of a carbonyl (C=O) with a H or R attached to the other side of the carbon [H(C=O)-]." The structure being described is:



(2) Determine if the structure drawn corresponds to the name given in the statement.

(A) stated that the above structure is called a carboxylic acid. You know from studying the tutorial that this group is called an aldehyde not a carboxylic acid. So statement (A) is not correct and can be discarded as a possible answer.

Repeat these steps for each possible answer.

The correct answer is (B).

Question No. 5 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 5. Which is the correct definition of an Arrhenius base?

(A) A substance that dissociates to give the hydroxide ion ($^{-}$OH).
(B) A substance that accept a proton (H^{+}).
(C) A substance that can donate a pair of electrons to form new bonds.
(D) A substance that can accept a pair of electrons to form new bonds.
(E) A substance formed when the Bronsted-Lowery acid donates a proton.

Feedback

A. Correct!
An Arrhenius base is a substance that dissociates to give the hydroxide ion ($^{-}$OH).

B. Incorrect!
A substance that accepts a proton is called a Bronsted-Lowry base. Go back and review the differences between Arrhenius, Bronsted-Lowry, and Lewis bases.

C. Incorrect!
A substance that can donate a pair of electrons to form new bonds is called a Lewis base. Go back and review the differences between Arrhenius, Bronsted-Lowry, and Lewis bases.

D. Incorrect!
A substance that can accept a pair of electrons to form new bonds is called a Lewis acid. Go back and review the three categories of acids and bases.

E. Incorrect!
A substance formed when the Bronsted-Lowery acid donates a proton is called a conjugate base. Go back and review the three categories of acids and bases.

Solution

(1) Recall the different types of acids and bases.

There are three theories of acidity and basicity that are commonly used in organic chemistry: Arrhenius, Bronsted-Lowry, and Lewis. They evolved as our understanding of how acids and bases work increased.

The Arrhenius theory defines acids and bases as substances that disassociates in water to form the hydronium ion (H_3O^{+}) or hydroxide ion ($^{-}$OH) respectively.

The Bronsted-Lowry theory defines an acid as a substance that donates a proton (H^{+}) and a base as a substance that accepts a proton.

The Lewis theory defines an acid as a substance that can accept a pair of electrons to form a new bond while a base can donate a pair of electrons to form a new bond.

(2) Determine which type of acid or base each statement above is describing.

Statement (A) is describing an Arrhenius base.
Statement (B) is describing a Bronsted-Lowry base.
Statement (C) is describing a Lewis base.
Statement (D) is describing a Lewis acid.

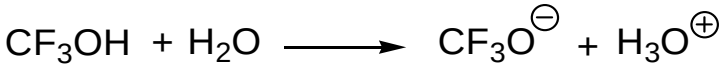
Therefore, the correct answer is (A).

Question No. 6 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 6. Identify the Bronsted-Lowry acid in the reaction below:



(A) CF_3OH
(B) H_2O
(C) CF_3O^-
(D) H_3O^+
(E) None of the above.

Feedback

A. Correct!
A Bronsted-Lowry acid is defined as a substance that can donate a proton (H^+). In this case, it is the CF_3OH that is donating the proton to water.

B. Incorrect!
Water is not acting as the Bronsted-Lowry acid in this reaction. To determine water's role, look at the equation. How did water change going from the left side of the equation to the right side?

C. Incorrect!
In this reaction, the CF_3O^- is the conjugate base. Review the definition of conjugate base and then work backwards to determine the Bronsted-Lowry acid.

D. Incorrect!
In this reaction, the hydronium ion (H_3O^+) is the conjugate acid. Review the definition of conjugate acid and then work backwards to determine the Bronsted-Lowry acid.

E. Incorrect!
The answer is included as one of the above answer choices. Go back and review the Bronsted-Lowry acid-base theory.

Solution

(1) Recall the definition of a Bronsted-Lowry acid.

A Bronsted-Lowry acid is a substance that can donate a proton (H^+).

(2) Look at the chemical equation and determine which species gives up a proton.

In a chemical equation, reactants are typically listed on the left side of the arrow and products are listed on the right side of the arrow. In the equation above, CF_3OH and H_2O are the reactants. Look how each reactant changes. Water gains a proton to become the hydronium ion (H_3O^+). The CF_3OH loses a proton to become CF_3O^-.

By definition, the CF_3OH is the Bronsted-Lowry acid.

Therefore the correct answer is (A).

Question No. 7 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 7. Give the name of the substance that can donate a pair of electrons to form new bonds.

(A) Bronsted-Lowry base
(B) Lewis acid
(C) Lewis base
(D) Arrhenius acid
(E) Arrhenius base

Feedback

A. Incorrect!
By definition, a Bronsted-Lowry base is a substance that can accept a proton (H^+).

B. Incorrect!
By definition, a Lewis acid is a substance that can accept a pair of electrons to form a new bond.

C. Correct!
By definition, a Lewis base is a substance that can donate a pair of electrons to form a new bond. An example would be the chloride ion (Cl^-) donating a pair of electrons to a proton (H^+) to form a molecule of hydrochloric acid (HCl).

D. Incorrect!
By definition, an Arrhenius acid is a substance that disassociates to give a proton (H^+).

E. Incorrect!
By definition, an Arrhenius base is a substance that disassociates to give hydroxide ion (^-OH).

Solution

(1) Recall the different types of acids and bases.

There are three theories of acidity and basicity that are commonly used in organic chemistry: Arrhenius, Bronsted-Lowry, and Lewis. They evolved as our understanding of how acids and bases work increased.

The Arrhenius theory defines acids and bases as substances that disassociates in water to form the hydronium ion (H_3O^+) or hydroxide ion (^-OH) respectively.

The Bronsted-Lowry theory defines an acid as a substance that donates a proton (H^+) and a base as a substance that accepts a proton.

The Lewis theory defines an acid as a substance that can accept a pair of electrons to form a new bond while a base can donate a pair of electrons to form a new bond.

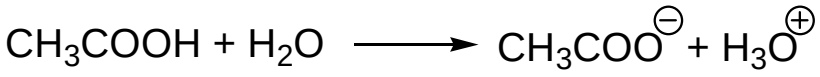
Therefore, the correct answer is (C).

Question No. 8 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 8. Consider the reaction below and then identify the statement that is ***incorrect***.



(A) Though water is amphoteric, it is reacting here as a Bronsted-Lowry base.
(B) In this reaction, the acetate ion (CH_3COO^-) is the conjugate base.
(C) In this reaction, the hydronium ion (H_3O^+) is the conjugate acid.
(D) In this reaction, CH_3COOH is the conjugate acid.
(E) In this reaction, water is acting as both a Bronsted-Lowry base and a Lewis base.

Feedback

A. Incorrect!
This statement is correct. Amphoteric is used to describe a substance that can react as an acid or a base. Water is amphoteric and in this particular instance, it is accepting a proton so it is reacting as a Bronsted-Lowry base.

B. Incorrect!
This statement is correct. The acetate ion (CH_3COO^-) is the conjugate base (a base that results from the Bronsted-Lowry acid losing a proton.).

C. Incorrect!
This statement is correct. The hydronium ion (H_3O^+) is the conjugate acid (an acid that results from the Bronsted-Lowry base accepting a proton.)

D. Correct!
This statement is incorrect. The CH_3COOH is the Bronsted-Lowry acid in this reaction. The conjugate acid is formed when the Bronsted-Lowry base (in this case, water) gains a proton.

E. Incorrect!
This statement is correct. The water acts as a Bronsted-Lowry base and accepts a proton. However, water is also donating one of its lone pairs to form a bond with the proton so it is acting as a Lewis base too.

Solution

(1) Read each statement carefully. You are looking for the incorrect statement.

(2) Recall the definitions of Bronsted-Lowry acid, Bronsted-Lowry base, amphoteric, Lewis base, conjugate acid, and conjugate base.

A Bronsted-Lowry acid is a substance that donates a proton (H^+).

A Bronsted-Lowry base is a substance that accepts a proton (H^+).

Amphoteric is used to describe a substance that can react as an acid or a base.

A conjugate acid is an acid that results from the Bronsted-Lowry base accepting a proton.

A conjugate base is a base that results from the Bronsted-Lowry acid losing a proton.

A Lewis base is a compound that donates a pair of electrons to form a bond with another atom.

(3) Based on these definitions, determine which statements are correct.

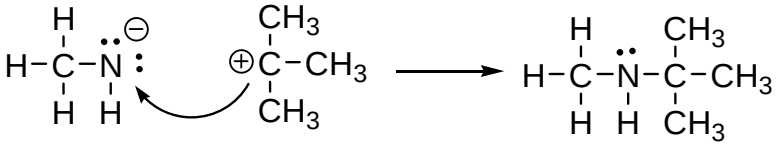
Therefore, the correct answer is (D).

Question No. 9 of 10

Instruction: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 9. Which statement about the mechanism below is ***incorrect***?



(A) The nitrogen is the most electronegative atom present and serves as the nucleophile.
(B) The mechanism above correctly depicts the flow of electrons as from the least electronegative atom to the most electronegative atom.
(C) The carbocation is the electrophile because it accepts electrons in the mechanism.
(D) The bond that is formed in the reaction is a polar covalent bond.
(E) Formation of the bond between nitrogen and carbon gives the positively charged carbon a full octet.

Feedback

A. Incorrect!
This statement correctly describes the mechanism shown. Nitrogen is more electronegative than carbon or hydrogen. Here, with two bonds and two lone pairs, the nitrogen has a formal charge of -1.

B. Correct!
The rules for drawing mechanisms state that the flow of electrons in a mechanism is from the most electronegative atom to the least electronegative atom. This means the curved arrow above is incorrect. It is drawn from the positively charged carbon to the negatively charged nitrogen. The arrow should be drawn in the opposite direction—from the nitrogen to the carbon.

C. Incorrect!
This statement correctly describes the mechanism shown. The positively charged carbon of the carbocation is lacking a pair of electrons. It can accept a pair of electrons from the negatively nitrogen to completely fill its octet.

D. Incorrect!
This statement correctly describes the mechanism shown. The new bond between the nitrogen and the carbon is a polar covalent bond due to the differences in the electronegativities of the two atoms.

E. Incorrect!
This statement correctly describes the outcome of the bond formation. The once electron deficient carbon now has a full octet.

Solution

(1) Read each statement carefully. You are looking for the incorrect statement.

(2) Recall the rules for drawing a mechanism.

Identify the nucleophile. It will donate electrons in the mechanism.

Identify the electrophile. It will accept electrons in the mechanism.

The flow of electrons is from the most electronegative atom to the least electronegative atom.

(3) Determine which of the above statements are correct based on this information.

Statement (A) is correct because nitrogen is the most electronegative atom present and it donates a pair of electrons to the carbocation.

Statement (B) is incorrect. The flow of electrons in a mechanism should be from the most electronegative atom to the least electronegative atom. Here, the electron flow is pictured going from the least electronegative to the most electronegative atom.

Statement (C) is correct because the carbocation is the electrophile and accepts electrons from the nitrogen.

Statement (D) is correct. The new bond between the nitrogen and the carbon is a polar covalent bond due to the differences in the electronegativities of the two atoms.

Statement (E) is correct. The once electron deficient carbon now has a full octet because of the bond formed with the nitrogen.

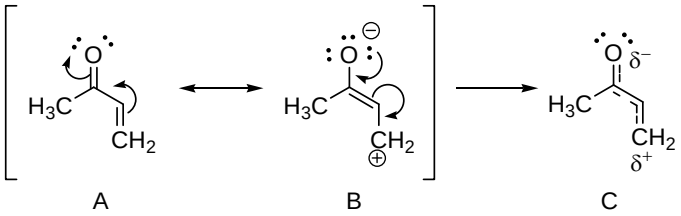
Therefore, the correct answer is (B).

Question No. 10 of 10

Instructions: (1) Read the problem statement and answer choices carefully (2) Work the problems on paper as needed (3) Pick the answer (4) Go back to review the core concept tutorial as needed.

Question

Question 10. Consider the structures labeled A through C below. Which statement describing them is ***incorrect***?



A B C

(A) A and B are valid resonance structures.
(B) C is a resonance hybrid.
(C) The resonance hybrid shows the pi electrons are delocalized over three atoms.
(D) The curved arrows show the flow of electrons that give rise to each resonance structure.
(E) Delocalization of electrons is stabilizes a molecule by lowering its energy.

Feedback

A. Incorrect!
Structures A and B are valid resonance structures of each other. They are equivalent structures that differ only in the placement of electrons.

B. Incorrect!
Structure C is a resonance hybrid. The resonance hybrid is a composite of the various contributing resonance structures.

C. Correct!
The above resonance structure shows the pi electrons to be delocalized over four atoms not three.

D. Incorrect!
The curved arrows do indicate electron flow and by following the arrows, one can determine the placement of the electrons in the next structure.

E. Incorrect!
By sharing electrons over several atoms, delocalization lowers a molecule's overall energy.

Solution

(1) Recall the definitions of resonance structures and resonance hybrid.

Resonance structures are equivalent structures that differ only in the placement of electrons. One structure by itself does not give an accurate picture of the molecule.

The resonance hybrid is a composite of the various contributing resonance structures and gives a more accurate picture of the molecule.

(2) Read each statement carefully and determine which one is incorrect.

A and B are resonance structures of the same molecule. Both obey the rules for drawing covalent structures and the constitution of the molecule remained constant in both structures. Only the placement of the electrons differs. Statement (A) is correct.

C is a composite of the two resonance structures so it serves as the resonance hybrid. Since the hybrid is a composite of the resonance structures, it does give a more accurate picture of the molecule. Therefore, statement (B) is correct.

The hybrid shows the areas of delocalized electrons through the use of dashed lines. In the above example, the dashed line goes from the oxygen to the carbon of the sp^2 hybridized $–CH_2$. This indicates the electrons are delocalized over 4 atoms—not three as stated in statement (C).

The curved arrows in the above example do indicate electron flow. By following the arrows, one can determine where the electrons will be located in the next structure. Statement (D) is correct.

Delocalization of electrons does lower a molecule's energy. Statement (E) is correct.

Therefore, the correct answer is (C).