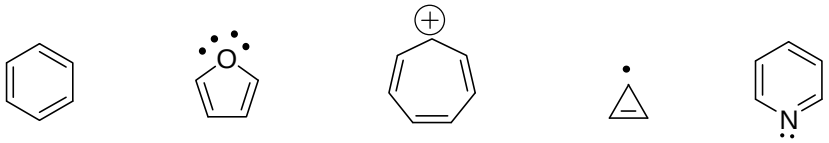
Question No. 1 of 10

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 compound below is not aromatic?



I II III IV V

(A) I
(B) II
(C) III
(D) IV
(E) V

Feedback

A. Incorrect!
Benzene is aromatic. It is a ring with continuously overlapping p orbitals. It also contains a Huckel number of pi electrons: 6 pi electrons.

B. Incorrect!
Furan is aromatic. The oxygen is sp^2 hybridized so one of the lone pairs on the oxygen resides in a p orbital and can interact with the other pi electrons. Including the oxygen lone pair in the p orbital, there are a Huckel number of pi electrons: 6.

C. Incorrect!
The cycloheptyl cation is aromatic. It is a ring with continuously overlapping p orbitals (remember that carbocations are sp^2 hybridized.). It also contains a Huckel number of pi electrons: 6 pi electrons.

D. Correct!
The cyclopropyl radical is not aromatic. While the cyclopropyl radical is a ring with overlapping p orbitals (recall that carbon radicals are sp^2 hybridized), the molecule does not contain a Huckel number of electrons. There are three pi electrons. If you set 3 equal to 4n+2 and solve for n, you will find that n is a fraction.

E. Incorrect!
Pyridine is aromatic. The three pi bonds gives a Huckel number of pi electrons. The lone pair on the nitrogen resides in one of the sp^2 hybridized orbitals.

Solution

(1) Recall the criteria for aromaticity.

First, the molecule must be cyclic and planar. Second, there must be a continuous ring of overlapping p orbitals. And third, the molecule must obey Huckel's rule (the total number of pi electrons must be such that when set equal to 4n+2 and solved for n, that n is a whole number).

(2) Check to see if all compounds are cyclic.

All the possible choices are cyclic.

(3) Check to see if each ring has a continuous ring of overlapping p orbitals.

This criterion means each atom in the ring must be sp^2 hybridized. All the possible choices fit this requirement. Remember that carbocations and radicals are sp^2 hybridized. Also, heteroatoms are often the same hybridization as the carbon atoms attached to them so you could deduce II (furan) and V (pyridine) as having a continuous ring of overlapping p orbitals.

(4) Check to see if each molecule has a Huckel number of pi electrons.

Count the number of pi electrons in each molecule. Remember, anions are counted as 2 pi electrons, cations as 0 pi electrons, and radicals as 1 pi electron. Set the total number of pi electrons for each molecule equal to 4n+2 and solve for n. In order for the compound to be aromatic, n must be a whole number.

The only molecule that does not fit this criterion is IV.

Therefore, the correct answer is (D).

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. Which statement about benzene is correct?

(A) The hybridization of the carbons in the ring alternate between sp^3 and sp^2.
(B) The bond angles are all 109.5 degrees.
(C) The carbons are trigonal pyramidal.
(D) The ring has 6 pi electrons.
(E) Isaac Newton proposed its structure.

Feedback

A. Incorrect!
All the carbons in a benzene ring are sp^2 hybridized. Go back and review the structure of benzene.

B. Incorrect!
The bond angles in benzene are 120 degrees not 109.5 degrees. Go back and review the structure of benzene.

C. Incorrect!
The carbons in benzene are trigonal planar in shape and not trigonal pyramidal. Go back and review the structure of benzene.

D. Correct!
Benzene has 6 pi electrons. According to Huckel's Rule, the ring is considered aromatic.

E. Incorrect!
Kekule proposed its structure in 1865. Go back and review the structure and history of benzene.

Solution

(1) Recall what you learned about the structure of benzene.

The structure of benzene was originally proposed by Kekule in 1865. It is a six-membered ring containing all carbons. The carbons are sp^2 hybridized, trigonal planar and have bond angles of 120 degrees. As a result, the ring is flat. It contains 6 pi electrons in three carbon-carbon double bonds that alternate with single bonds. It meets all the criteria for an aromatic compound according to Huckel's rule.

(2) Read the question carefully and determine the correct answer.

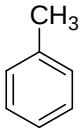
Therefore, the correct answer is (D).

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. What is the common name of the compound below?



(A) Phenol
(B) Aniline
(C) Anisole
(D) Styrene
(E) Toluene

Feedback

A. Incorrect!
Phenol is a benzene ring bonded to a hydroxyl group. Go back and review the common names for benzene and its derivatives.

B. Incorrect!
Aniline is a benzene ring bonded to an amino group. Go back and review the common names for benzene and its derivatives.

C. Incorrect!
Anisole is a benzene ring bonded to a methoxy group. Go back and review the common names for benzene and its derivatives.

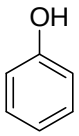
D. Incorrect!
Styrene is a benzene ring bonded to an ethylene group. Go back and review the common names for benzene and its derivatives.

E. Correct!
Toluene is a compound where a methyl group is bonded to a benzene ring.

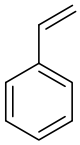
Solution

(1) Recall the different common names for benzene derivatives.

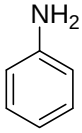
There are several common names for benzene derivatives so one must know not only their names but also their structures. Some examples are listed below:



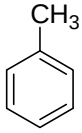
Phenol



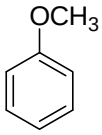
Styrene



Aniline



Toluene



Anisole

(2) Study the structure above and determine its correct name.

The structure shows a methyl group attached to a benzene ring.

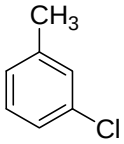
Therefore, the correct answer is (E).

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. What is the relationship between the two substituents on the ring below?



(A) Ortho
(B) Meta
(C) Para
(D) Trans
(E) Cis

Feedback

A. Incorrect!
Ortho indicates a 1,2 relationship on a benzene ring. Go back and review aromatic nomenclature.

B. Correct!
Meta indicates a 1,3 relationship on a benzene ring.

C. Incorrect!
Para indicates a 1,4 relationship on a benzene ring. Go back and review aromatic nomenclature.

D. Incorrect!
Trans refers to the orientation of similar groups on a double bond. Go back and review aromatic nomenclature.

E. Incorrect!
Cis refers to the orientation of similar groups on a double bond. Go back and review aromatic nomenclature.

Solution

(1) Recall the rules for aromatic nomenclature.

For disubstituted benzene derivatives, one can use the ortho-meta-para designation. These designations indicate where substituents are positioned on the ring in relation to each other.

Ortho indicates a 1,2 relationship between substituents.
Meta indicates a 1,3 relationship between substituents.
Para indicates a 1,4 relationship between substituents.

(2)Determine the relative positions of the substituents on the ring in the given molecule.

There are two substituents in this example: a methyl group and a chlorine atom. They are three carbons away from each other so they have a meta relationship.

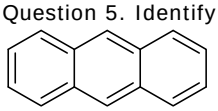
Therefore, the correct answer is (B).

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. Identify the compound below:



(A) Naphthalene
(B) Anthracene
(C) Phenanthrene
(D) Tribenzene
(E) Propylbenzene

Feedback

A. Incorrect!
Naphthalene is a structure where two benzene rings are fused together. Go back and review aromatic fused rings.

B. Correct!
Anthracene is a structure where three benzene rings are fused in a linear fashion.

C. Incorrect!
Phenanthrene is a structure where three benzene rings are fused in an L-shaped formation. Go back and review aromatic fused rings.

D. Incorrect!
The structure above is not tribenzene. Go back and review aromatic fused rings in the tutorial.

E. Incorrect!
Propylbenzene is a benzene ring with a propyl group attached to it. Go back and review aromatic fused rings.

Solution

(1) Recall the nomenclature for aromatic fused rings from the tutorial.

Three aromatic fused ring structures were mentioned in the tutorial. Naphthalene, anthracene, and phenanthrene.

Naphthalene is constructed of two benzene rings fused together. Anthracene is constructed of three benzene rings fused together in a linear fashion. Phenanthrene is constructed of three benzene rings fused together in an L-shaped fashion.

(2) Study the structure above and determine the correct answer.

The structure above is of three benzene rings fused in a linear fashion. The compound is anthracene.

Therefore, the correct answer is (B).

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. Which statement about electrophilic aromatic substitution is incorrect?

(A) In the first step of the mechanism, the pi electrons in the benzene ring acts as the nucleophile and attack the electrophile.
(B) A benzenium ion is formed from the ring's pi electrons attacking the electrophile.
(C) In the last step of the mechanism, a base extracts a proton from the benzenium ion which leads to the re-establishment of the ring's aromaticity.
(D) Benzene's pi electrons attacking the electrophile is the fast step of the mechanism while base extraction of a proton is the slow step.
(E) The benzenium ion formed often has several resonance structures that can be drawn for it.

Feedback

A. Incorrect!
In electrophilic aromatic substitution, the first step of the mechanism involves the benzene ring's electrons attacking the electrophile. Go back and review the mechanistic steps of electrophilic aromatic substitution.

B. Incorrect!
The carbocation intermediate formed in electrophilic aromatic substitution reactions is a benzenium ion. It is formed when the pi electrons attack the electrophile. Go back and review the mechanistic steps of electrophilic aromatic substitution.

C. Incorrect!
The final step in the mechanism of electrophilic aromatic substitution is the re-establishment of the ring's aromaticity by extraction of a proton from the intermediate carbocation.

D. Correct!
This statement is incorrect. The slow step in the mechanism is the first step: formation of the benzenium ion which results when the pi electrons attack the electrophile. The fast step is extraction of a proton from the carbocation intermediate.

E. Incorrect!
The benzenium cation often does have several resonance structures that may be drawn for it. Go back and review the mechanistic steps of electrophilic aromatic substitution.

Solution

(1) Recall the details of electrophilic aromatic substitution's mechanism.

The first step of the mechanism occurs when the pi electrons of the aromatic ring attack an electrophile. It is the slowest step in the mechanism because (1) the ring loses it aromaticity, a great source of stability, and (2) a carbocation is formed. While the carbocation intermediate is resonance stabilized, it is still a high energy, relatively unstable intermediate.

The last step of the mechanism involves the extraction of a proton from the ring. This results in the formation of a third double bond in the ring and re-establishes the ring's aromaticity. The extraction of the proton is the fast step of the mechanism since results in a more stable product.

(2) Read each statement carefully and choose the one that is incorrect.

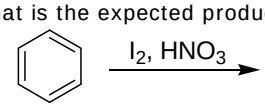
Therefore, the correct answer is (D).

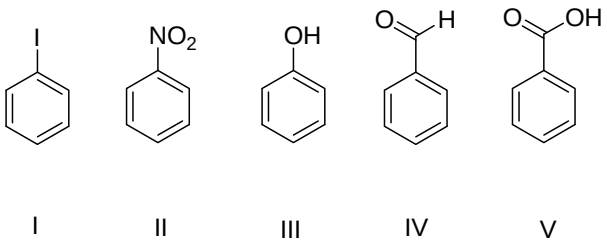
Question No. 7 of 10

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. What is the expected product of the reaction below?





I II III IV V

(A) I
(B) II
(C) III
(D) IV
(E) V

Feedback

A. Correct!
Iodobenzene is the product that would be obtained under these reaction conditions. The reaction occurs via an electrophilic aromatic substitution mechanism.

B. Incorrect!
Nitrobenzene would not be obtained under these reaction conditions. Go back and review the different compounds that may be obtained from electrophilic aromatic substitution reactions.

C. Incorrect!
Phenol would not be obtained under these reaction conditions. Go back and review the different compounds that may be obtained from electrophilic aromatic substitution reactions.

D. Incorrect!
Benzaldehyde would not be obtained under these reaction conditions. Go back and review the different compounds that may be obtained from electrophilic aromatic substitution reactions.

E. Incorrect!
Benzoic acid would not be obtained under these reaction conditions. Go back and review the different compounds that may be obtained from electrophilic aromatic substitution reactions.

Solution

(1) Recall the information on electrophilic aromatic substitution reactions.

There are several types of reactions that occur via an electrophilic aromatic substitution mechanism. These include:

(a) halogenation where a halogenated benzene is obtained.
(b) nitration where nitrobenzene is obtained.
(c) sulfonation where benzenesulfonic acid is obtained.
(d) Friedel-Craft alkylation where an alkyl benzene is obtained.
(e) Friedel-Craft acylation where an aromatic ketone is obtained.

(2) Study the above reaction and determine the correct answer.

Iodine in the presence of nitric acid will halogenate a benzene ring. Iodobenzene is obtained as the product.

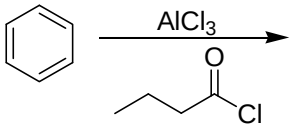
Therefore , the correct answer is (A).

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. What type of product is expected from this reaction?



(A) Acid chloride
(B) Aldehyde
(C) Ketone
(D) Alkyl chloride
(E) Alcohol

Feedback

A. Incorrect!
An acid chloride would not be obtained under these conditions. Go back and review the Friedel-Craft acylation.

B. Incorrect!
An aldehyde would not be obtained under these conditions. Go back and review the Friedel-Craft acylation.

C. Correct!
A ketone is the product of the Friedel-Craft acylation. It occurs via an electrophilic aromatic substitution mechanism.

D. Incorrect!
An alkyl chloride would not be obtained under these conditions. Go back and review the Friedel-Craft acylation.

E. Incorrect!
An alcohol would not be obtained under these conditions. Go back and review the Friedel-Craft acylation.

Solution

(1) Recall the reactions covered in this tutorial.

The tutorial covered reactions of aromatic compounds.

(2) Determine what kind of reaction is taking place.

To determine what kind of reaction is taking place, you will first need to identify the reactants being used in the reaction.

The starting material is benzene. The other reactants are aluminum trichloride and an acid chloride. You may have already recognized this reaction as a Friedel-Craft acylation. If you did not, go back and review the reactions in this tutorial.

It is not enough to just recognize the type of reaction taking place. You must also understand the mechanism in order to accurately predict the product. Recall that the Friedel-Craft acylation occurs via an electrophilic aromatic substitution reaction. An acid chloride reacts initially with aluminum trichloride to form an electrophilic acylium ion. The acylium ion is attacked by the pi electrons in benzene to form a benzenium ion which undergoes deprotonation to re-establish the aromaticity of the benzene ring. The product of the Friedel-Craft acylation is an aromatic ketone.

(3) Determine the product of the reaction above.

The reaction above includes $AlCl_3$ and an acid chloride. It is a Friedel-Craft acylation so one would expect the product to be an aromatic ketone.

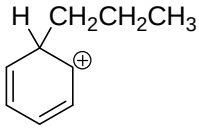
Therefore, the correct answer is (C).

Question No. 9 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 9. How many additional resonance structures may be drawn for the structure below (*i.e.* do not count the one shown in your calculations) :



(A) 0
(B) 1
(C) 2
(D) 3
(E) 4

Feedback

A. Incorrect!
Additional resonance structures can be drawn for the cation above. Go back and review its structure and see if you can determine what the additional resonance structures might look like.

B. Incorrect!
Additional resonance structures can be drawn for the cation above. Go back and review its structure and see if you can determine what the additional resonance structures might look like.

C. Correct!
One may draw an additional two resonance structures for the cation above.

D. Incorrect!
Less than three additional resonance structures can be drawn for the cation above. Go back and review its structure and see if you can determine what the additional resonance structures might look like.

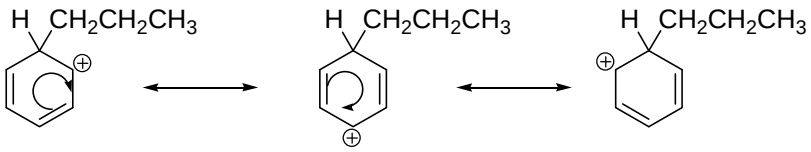
E. Incorrect!
Less than four additional resonance structures can be drawn for the cation above. Go back and review its structure and see if you can determine what the additional resonance structures might look like.

Solution

(1) Recall the benzenium ion and how it is resonance stabilized.

The benzenium ion is an intermediate of electrophilic aromatic substitution reactions. A pair of pi electrons in benzene will attack an electrophile forming a positively charged ion. This cation is resonance stabilized and as a result one may draw equivalent resonance structures for the cation.

(2) How many resonance structures may be drawn for the cation above?



By attacking the positively charged carbon with the adjacent pi bond, one can form a second resonance structure. One may repeat the process once more to form a third structure.

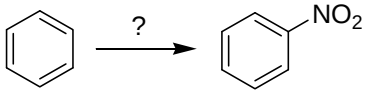
Therefore, the correct answer is (C).

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. What conditions would you use to achieve the transformation below?



(A) Cl_2, $AlCl_3$
(B) Br_2, $FeBr_3$
(C) SO_3, H_2SO_4
(D) I_2, HNO_3
(E) HNO_3, H_2SO_4

Feedback

A. Incorrect!
Nitrobenzene would not be obtained under these conditions. Go back and review the conditions for nitration of benzene.

B. Incorrect!
Nitrobenzene would not be obtained under these conditions. Go back and review the conditions for nitration of benzene.

C. Incorrect!
Nitrobenzene would not be obtained under these conditions. Go back and review the conditions for nitration of benzene.

D. Incorrect!
Nitrobenzene would not be obtained under these conditions. Go back and review the conditions for nitration of benzene.

E. Correct!
Nitric acid in the presence of sulfuric acid will nitrate a benzene ring.

Solution

(1) Recall the reactions covered in this tutorial.

The tutorial covered reactions of aromatic compounds. The reactions covered occur via an electrophilic aromatic substitution mechanism.

(2) Determine what kind of reaction is taking place.

The starting material is benzene and the product is nitrobenzene. The student is asked to determine the reaction conditions that lead to the final product. The only reagents that will nitrate a benzene ring are nitric acid together with sulfuric acid.

Therefore, the correct answer is (E).