

Chapter 2--Polar Covalent Bonds; Acids and Bases

Student: _____

1. Exhibit 2-1

Give the letter of the term that best matches the given definition.

- | | |
|------------------------|------------------------|
| a. Brønsted-Lowry Acid | f. Ionic Bond |
| b. Brønsted-Lowry Base | g. Covalent Bond |
| c. Lewis Acid | h. Polar-Covalent Bond |
| d. Lewis Base | i. Hydrophobic |
| e. Electronegativity | j. Hydrophilic |

_____ Any species that can accept electrons.

2. Exhibit 2-1

Give the letter of the term that best matches the given definition.

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| a. Brønsted-Lowry Acid | f. Ionic Bond |
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_____ A bond between two atoms differing in electronegativity by 0.5 - 2.

3. **Exhibit 2-1**

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_____ A term used to describe a "water loving" species.

4. **Exhibit 2-1**

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_____ A compound that can donate a proton.

5. **Exhibit 2-1**

Give the letter of the term that best matches the given definition.

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|----|---------------------|----|---------------------|
| a. | Brønsted-Lowry Acid | f. | Ionic Bond |
| b. | Brønsted-Lowry Base | g. | Covalent Bond |
| c. | Lewis Acid | h. | Polar-Covalent Bond |
| d. | Lewis Base | i. | Hydrophobic |
| e. | Electronegativity | j. | Hydrophilic |

_____ The ability of an atom to attract the shared electrons in a covalent bond.

6. **Exhibit 2-1**

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- | | | | |
|----|---------------------|----|---------------------|
| a. | Brønsted-Lowry Acid | f. | Ionic Bond |
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| e. | Electronegativity | j. | Hydrophilic |

_____ A term used to describe a "water fearing" species.

7. **Exhibit 2-1**

Give the letter of the term that best matches the given definition.

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| d. | Lewis Base | i. | Hydrophobic |
| e. | Electronegativity | j. | Hydrophilic |

_____ Any species that can donate electrons.

8. **Exhibit 2-1**

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|----|---------------------|----|---------------------|
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_____ A bond between two atoms differing in electronegativity by < 0.5 .

9. **Exhibit 2-1**

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| d. | Lewis Base | i. | Hydrophobic |
| e. | Electronegativity | j. | Hydrophilic |

_____ A compound that can accept a proton.

10. **Exhibit 2-1**

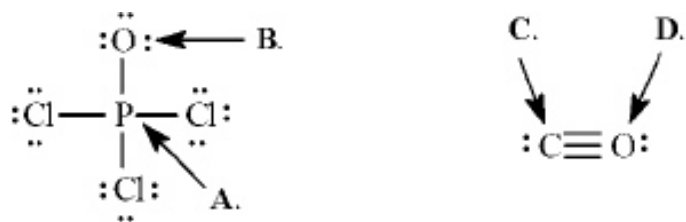
Give the letter of the term that best matches the given definition.

- | | | | |
|----|---------------------|----|---------------------|
| a. | Brønsted-Lowry Acid | f. | Ionic Bond |
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| c. | Lewis Acid | h. | Polar-Covalent Bond |
| d. | Lewis Base | i. | Hydrophobic |
| e. | Electronegativity | j. | Hydrophilic |

_____ A bond between two atoms differing in electronegativity by > 2 .

11. **Exhibit 2-2**

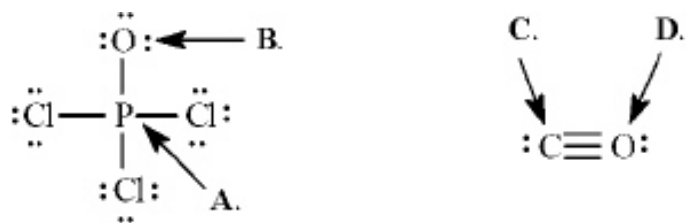
Calculate the formal charges on the indicated atoms in each compound below.



Refer to Exhibit 2-2. The formal charge on phosphorous (**A**) is _____.

12. **Exhibit 2-2**

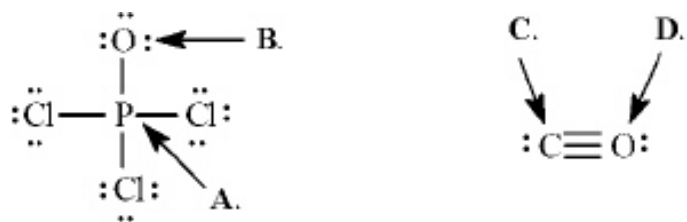
Calculate the formal charges on the indicated atoms in each compound below.



Refer to Exhibit 2-2. The formal charge on oxygen (**B**) is _____.

13. **Exhibit 2-2**

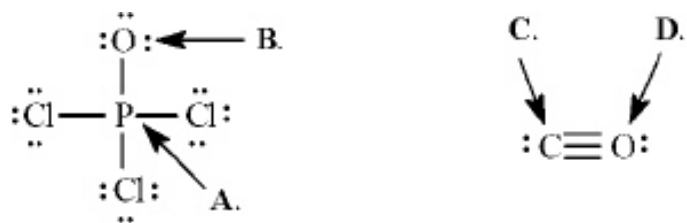
Calculate the formal charges on the indicated atoms in each compound below.



Refer to Exhibit 2-2. The formal charge on carbon (C) is _____.

14. **Exhibit 2-2**

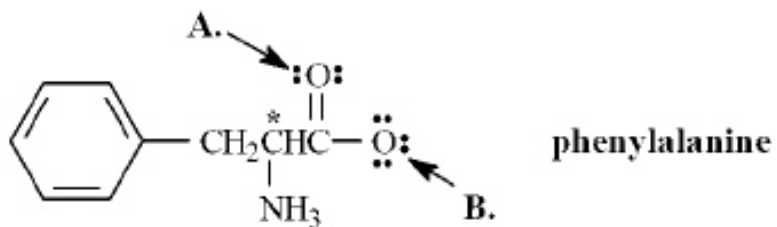
Calculate the formal charges on the indicated atoms in each compound below.



Refer to Exhibit 2-2. The formal charge on oxygen (D) is _____.

15. **Exhibit 2-3**

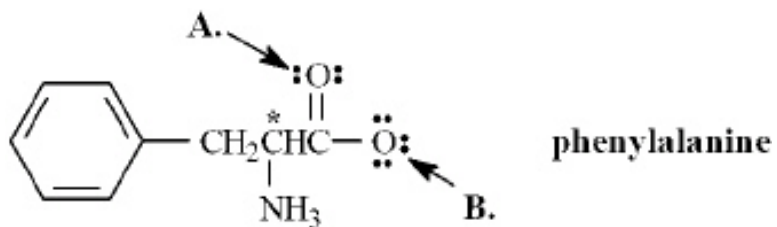
Phenylalanine is an amino acid that is essential to human nutrition. The representation below shows the structure of phenylalanine at physiological pH. Consider this structure to answer the following question(s).



Refer to Exhibit 2-3. Assign any formal charges to atoms in this representation of phenylalanine.

16. **Exhibit 2-3**

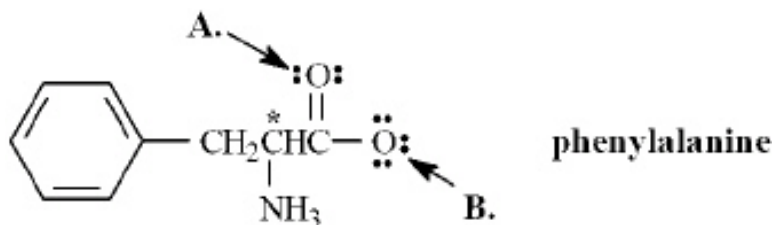
Phenylalanine is an amino acid that is essential to human nutrition. The representation below shows the structure of phenylalanine at physiological pH. Consider this structure to answer the following question(s).



Refer to Exhibit 2-3. The oxygen atom labeled **A.** has _____ non-bonding electrons.

17. **Exhibit 2-3**

Phenylalanine is an amino acid that is essential to human nutrition. The representation below shows the structure of phenylalanine at physiological pH. Consider this structure to answer the following question(s).

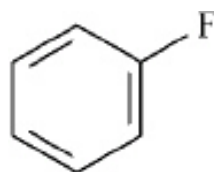


Refer to Exhibit 2-3. The oxygen atom labeled **B**. has _____ bonding electrons.

18. **Exhibit 2-4**

Use the δ^- / δ^+ convention and the crossed arrow ($\overleftrightarrow{+}$) to show the direction of the expected polarity of the indicated bonds in the following compounds.

Refer to Exhibit 2-4. The C-F bond in fluorobenzene,



19. **Exhibit 2-4**

Use the δ^- / δ^+ convention and the crossed arrow (\dashrightarrow) to show the direction of the expected polarity of the indicated bonds in the following compounds.

Refer to Exhibit 2-4. The C-Si bond in tetramethylsilane, $(\text{CH}_3)_4\text{Si}$

20. **Exhibit 2-4**

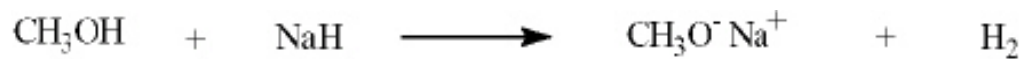
Use the δ^- / δ^+ convention and the crossed arrow (\dashrightarrow) to show the direction of the expected polarity of the indicated bonds in the following compounds.

Refer to Exhibit 2-4. The C-O bond in furan,



21. **Exhibit 2-5**

Label the acid, conjugate acid, base, and conjugate base in each reaction below.



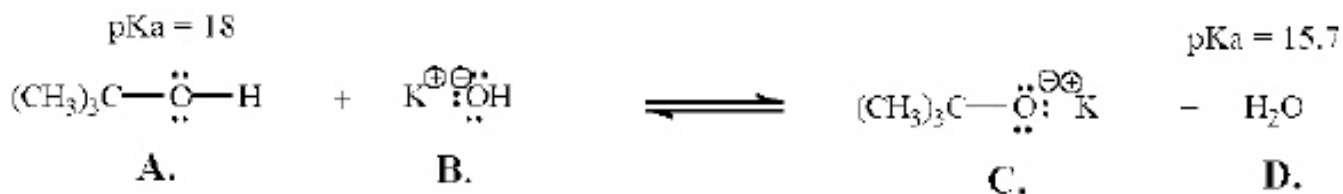
22. **Exhibit 2-5**

Label the acid, conjugate acid, base, and conjugate base in each reaction below.



23. **Exhibit 2-6**

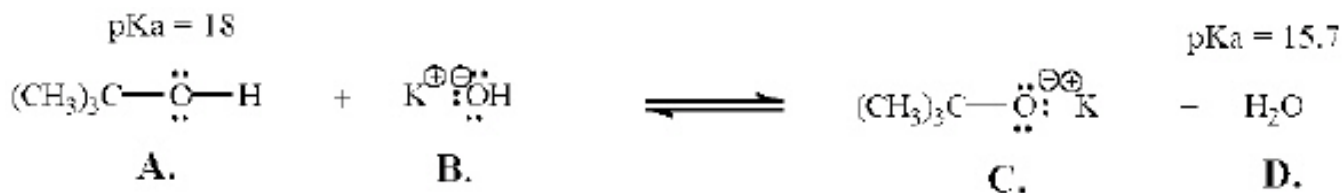
Refer to the following equation to answer the question(s) below. Place the letter corresponding to the correct answer in the blank.



Refer to Exhibit 2-6. The strongest Brønsted-Lowry acid in the equation is _____.

24. **Exhibit 2-6**

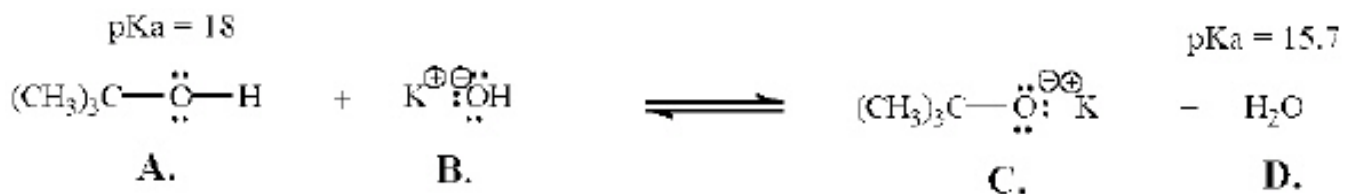
Refer to the following equation to answer the question(s) below. Place the letter corresponding to the correct answer in the blank.



Refer to Exhibit 2-6. The strongest Brønsted-Lowry base in the equation is _____.

25. **Exhibit 2-6**

Refer to the following equation to answer the question(s) below. Place the letter corresponding to the correct answer in the blank.

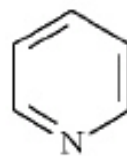
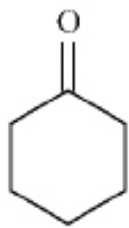
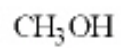


Refer to Exhibit 2-6. Will this reaction take place as written? Explain.

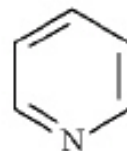
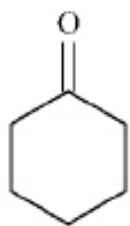
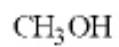
26. An acid with a low pK_a :

- is a weak acid
- is a strong acid
- has a weak conjugate base
- both b and c

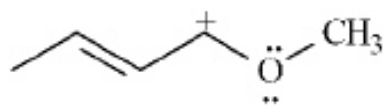
27. Circle all the Lewis bases in the group of compounds below.



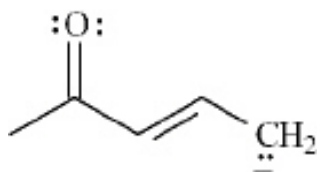
28. Put a box around all the Lewis acids in the group of compounds below.



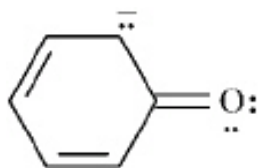
29. Draw *two* resonance structures for the species below.



30. Draw *two* resonance structures for the species below.



31. Draw *two* resonance structures for the species below.



32. **Exhibit 2-7**

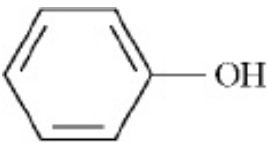
Consider the acidity constants below to answer the following question(s).

<u>ACID</u>	<u>STRUCTURE</u>	<u>pK_a</u>
phenol		10.00
ethanol	CH ₃ CH ₂ OH	16.00
water	HOH	15.74

Refer to Exhibit 2-7. Which acid will be almost completely deprotonated by NaOH?

33. **Exhibit 2-7**

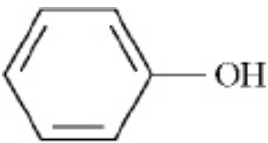
Consider the acidity constants below to answer the following question(s).

<u>ACID</u>	<u>STRUCTURE</u>	<u>pK_a</u>
phenol		10.00
ethanol	CH ₃ CH ₂ OH	16.00
water	HOH	15.74

Refer to Exhibit 2-7. Which acid has the *strongest* conjugate base?

34. **Exhibit 2-7**

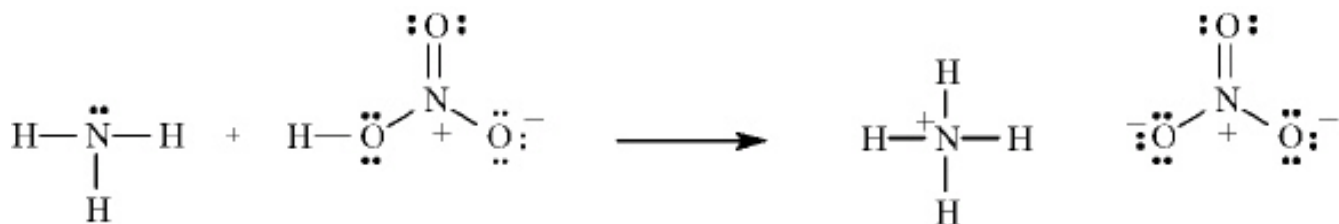
Consider the acidity constants below to answer the following question(s).

ACID	STRUCTURE	pK_a
phenol		10.00
ethanol	$\text{CH}_3\text{CH}_2\text{OH}$	16.00
water	HOH	15.74

Refer to Exhibit 2-7. Explain why phenol has a much lower pK_a than ethanol.

35. **Exhibit 2-8**

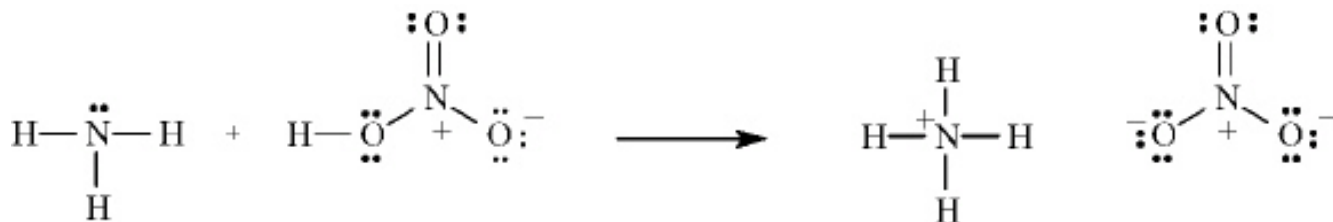
Consider the reaction below to answer the following question(s).



Refer to Exhibit 2-8. Using the curved arrow formalism, show the flow of electrons for this reaction.

36. **Exhibit 2-8**

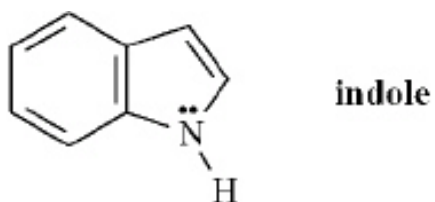
Consider the reaction below to answer the following question(s).



Refer to Exhibit 2-8. Label the acid and the base in the reaction.

37. **Exhibit 2-9**

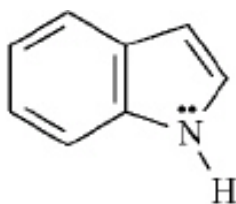
Indole is pleasant smelling in highly dilute solutions and has been used in perfumery. Use the structure of indole, below, to answer the following question(s).



Refer to Exhibit 2-9. Indole can function as a Brønsted-Lowry acid in the presence of strong bases. Formulate a reaction, showing electron flow with arrows, that demonstrates this reactivity of indole.

38. **Exhibit 2-9**

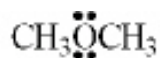
Indole is pleasant smelling in highly dilute solutions and has been used in perfumery. Use the structure of indole, below, to answer the following question(s).



indole

Refer to Exhibit 2-9. Indole can function as a Lewis base in the presence of strong acid. Formulate a reaction, showing electron flow with arrows, that demonstrates this reactivity of indole.

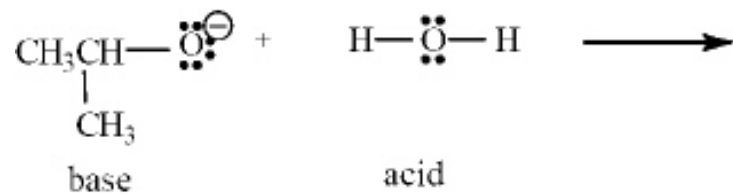
39. The condensed structure for dimethyl ether looks symmetrical. However, dimethyl ether has a dipole moment. Draw a structure that explains this and indicate the expected direction of the molecular dipole moment.



dimethyl ether

40. **Exhibit 2-10**

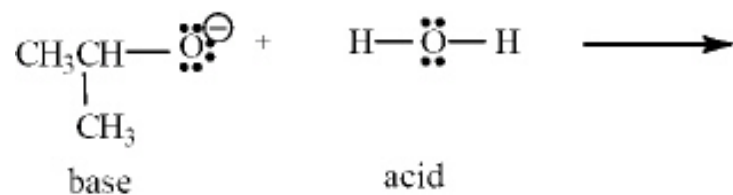
Consider the acid-base reaction below to answer the following question(s).



Refer to Exhibit 2-10. Using the curved arrow formalism, show the flow of electrons for this reaction.

41. **Exhibit 2-10**

Consider the acid-base reaction below to answer the following question(s).



Refer to Exhibit 2-10. Write the products of this Lewis acid - base reaction.

Chapter 2--Polar Covalent Bonds; Acids and Bases **Key**

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_____ Any species that can accept electrons.

c

2. **Exhibit 2-1**

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_____ A bond between two atoms differing in electronegativity by 0.5 - 2.

h

3. **Exhibit 2-1**

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_____ A term used to describe a "water loving" species.

j

4. **Exhibit 2-1**

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| c. Lewis Acid | h. Polar-Covalent Bond |
| d. Lewis Base | i. Hydrophobic |
| e. Electronegativity | j. Hydrophilic |

_____ A compound that can donate a proton.

a

5. **Exhibit 2-1**

Give the letter of the term that best matches the given definition.

- | | |
|------------------------|------------------------|
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| c. Lewis Acid | h. Polar-Covalent Bond |
| d. Lewis Base | i. Hydrophobic |
| e. Electronegativity | j. Hydrophilic |

_____ The ability of an atom to attract the shared electrons in a covalent bond.

e

6. **Exhibit 2-1**

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|------------------------|------------------------|
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_____ A term used to describe a "water fearing" species.

i

7. **Exhibit 2-1**

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|------------------------|------------------------|
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| c. Lewis Acid | h. Polar-Covalent Bond |
| d. Lewis Base | i. Hydrophobic |
| e. Electronegativity | j. Hydrophilic |

_____ Any species that can donate electrons.

d

8. **Exhibit 2-1**

Give the letter of the term that best matches the given definition.

- | | |
|------------------------|------------------------|
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| d. Lewis Base | i. Hydrophobic |
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_____ A bond between two atoms differing in electronegativity by < 0.5 .

g

9. **Exhibit 2-1**

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|------------------------|------------------------|
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| c. Lewis Acid | h. Polar-Covalent Bond |
| d. Lewis Base | i. Hydrophobic |
| e. Electronegativity | j. Hydrophilic |

_____ A compound that can accept a proton.

b

10. **Exhibit 2-1**

Give the letter of the term that best matches the given definition.

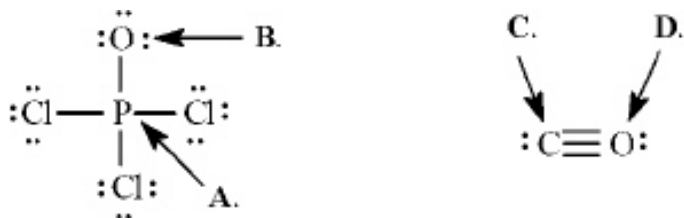
- | | |
|------------------------|------------------------|
| a. Brønsted-Lowry Acid | f. Ionic Bond |
| b. Brønsted-Lowry Base | g. Covalent Bond |
| c. Lewis Acid | h. Polar-Covalent Bond |
| d. Lewis Base | i. Hydrophobic |
| e. Electronegativity | j. Hydrophilic |

_____ A bond between two atoms differing in electronegativity by > 2 .

f

11. **Exhibit 2-2**

Calculate the formal charges on the indicated atoms in each compound below.

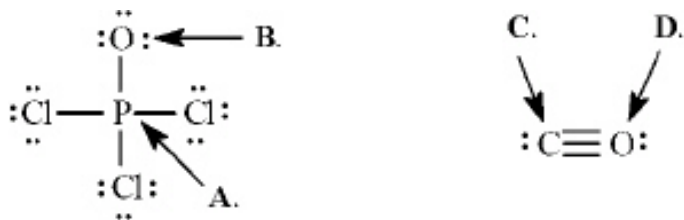


Refer to Exhibit 2-2. The formal charge on phosphorous (A) is _____.

+1

12. **Exhibit 2-2**

Calculate the formal charges on the indicated atoms in each compound below.

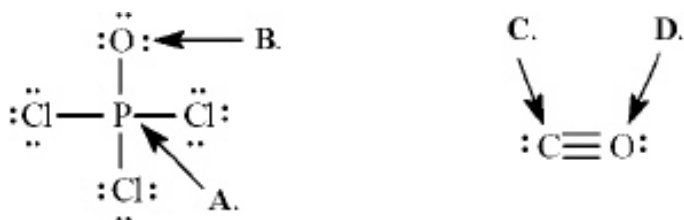


Refer to Exhibit 2-2. The formal charge on oxygen (**B**) is _____.

-1

13. **Exhibit 2-2**

Calculate the formal charges on the indicated atoms in each compound below.

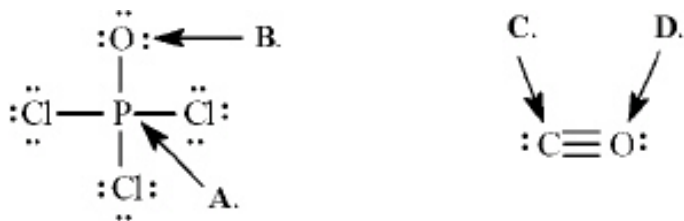


Refer to Exhibit 2-2. The formal charge on carbon (**C**) is _____.

-1

14. **Exhibit 2-2**

Calculate the formal charges on the indicated atoms in each compound below.

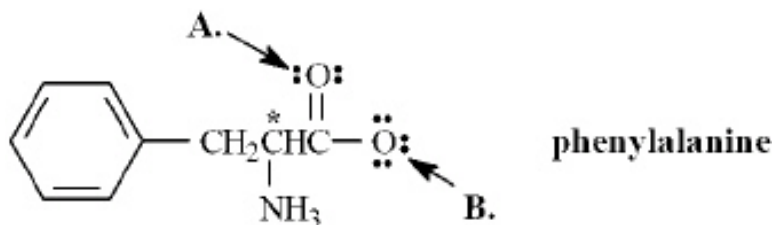


Refer to Exhibit 2-2. The formal charge on oxygen (**D**) is _____.

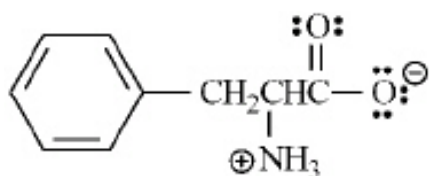
+1

15. **Exhibit 2-3**

Phenylalanine is an amino acid that is essential to human nutrition. The representation below shows the structure of phenylalanine at physiological pH. Consider this structure to answer the following question(s).

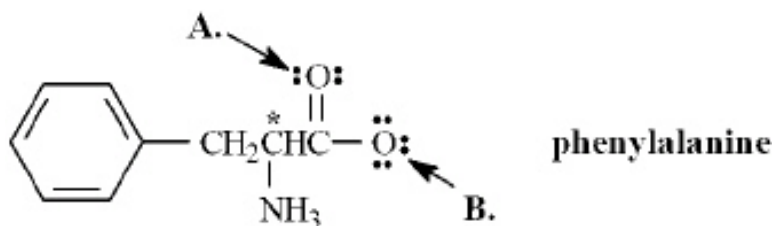


Refer to Exhibit 2-3. Assign any formal charges to atoms in this representation of phenylalanine.



16. **Exhibit 2-3**

Phenylalanine is an amino acid that is essential to human nutrition. The representation below shows the structure of phenylalanine at physiological pH. Consider this structure to answer the following question(s).

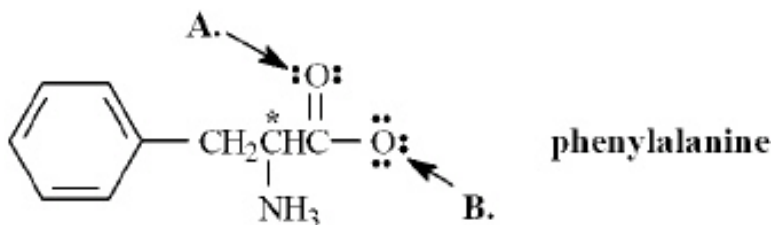


Refer to Exhibit 2-3. The oxygen atom labeled A. has _____ non-bonding electrons.

four

17. **Exhibit 2-3**

Phenylalanine is an amino acid that is essential to human nutrition. The representation below shows the structure of phenylalanine at physiological pH. Consider this structure to answer the following question(s).



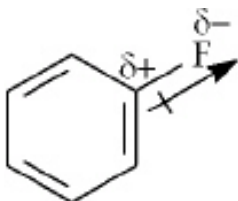
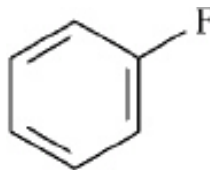
Refer to Exhibit 2-3. The oxygen atom labeled **B.** has _____ bonding electrons.

two

18. **Exhibit 2-4**

Use the δ^- / δ^+ convention and the crossed arrow (\rightarrow) to show the direction of the expected polarity of the indicated bonds in the following compounds.

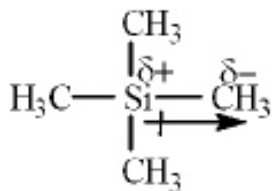
Refer to Exhibit 2-4. The C-F bond in fluorobenzene,



19. **Exhibit 2-4**

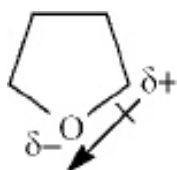
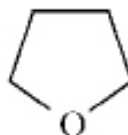
Use the δ^- / δ^+ convention and the crossed arrow (\rightarrow) to show the direction of the expected polarity of the indicated bonds in the following compounds.

Refer to Exhibit 2-4. The C-Si bond in tetramethylsilane, $(\text{CH}_3)_4\text{Si}$

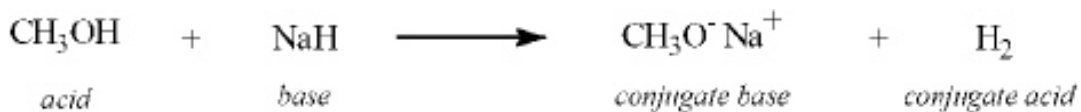
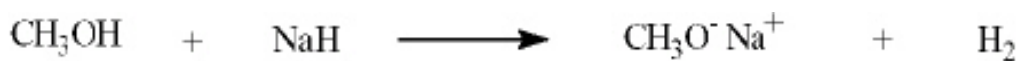
20. **Exhibit 2-4**

Use the δ^- / δ^+ convention and the crossed arrow (\rightarrow) to show the direction of the expected polarity of the indicated bonds in the following compounds.

Refer to Exhibit 2-4. The C-O bond in furan,

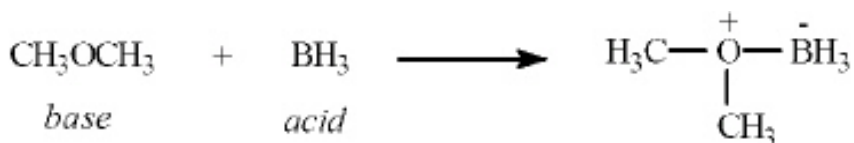
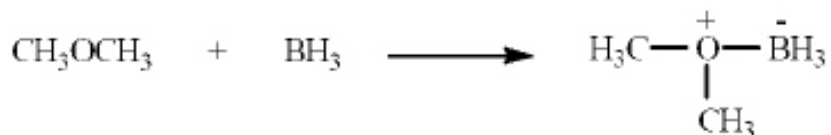
21. **Exhibit 2-5**

Label the acid, conjugate acid, base, and conjugate base in each reaction below.



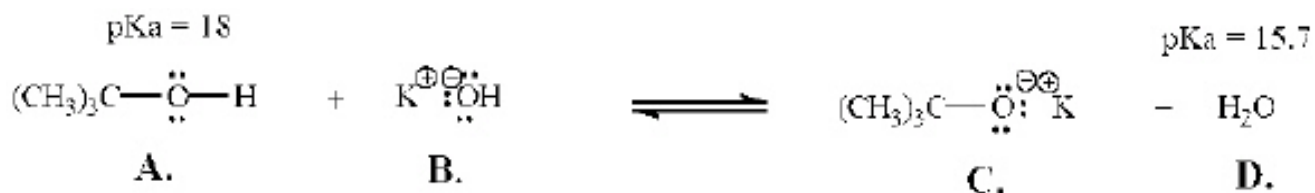
22. **Exhibit 2-5**

Label the acid, conjugate acid, base, and conjugate base in each reaction below.



23. **Exhibit 2-6**

Refer to the following equation to answer the question(s) below. Place the letter corresponding to the correct answer in the blank.

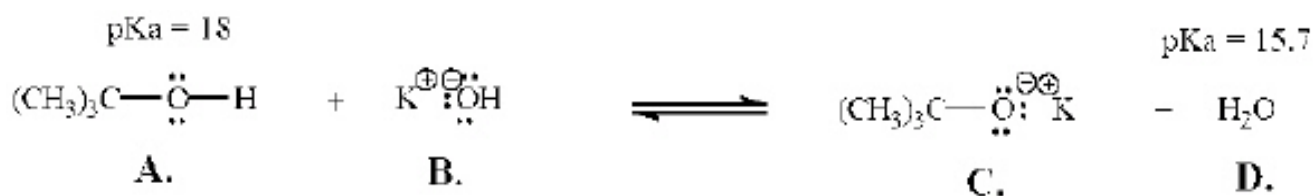


Refer to Exhibit 2-6. The strongest Brønsted-Lowry acid in the equation is _____.

D

24. **Exhibit 2-6**

Refer to the following equation to answer the question(s) below. Place the letter corresponding to the correct answer in the blank.

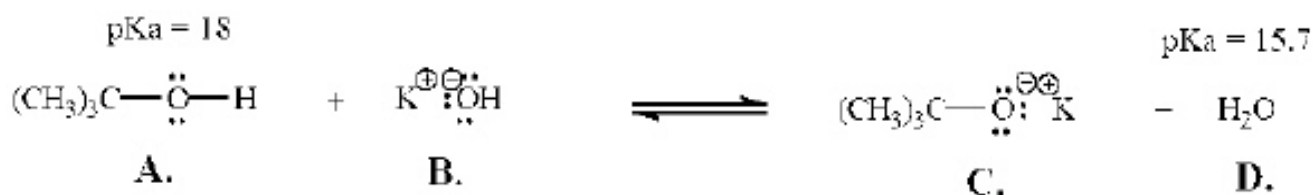


Refer to Exhibit 2-6. The strongest Brønsted-Lowry base in the equation is _____.

C

25. **Exhibit 2-6**

Refer to the following equation to answer the question(s) below. Place the letter corresponding to the correct answer in the blank.



Refer to Exhibit 2-6. Will this reaction take place as written? Explain.

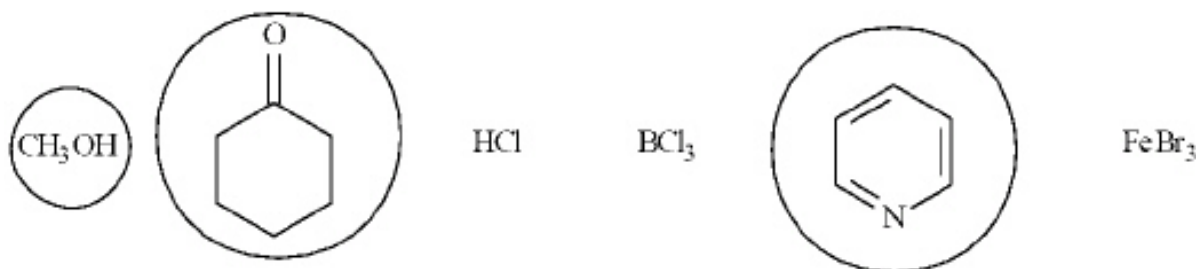
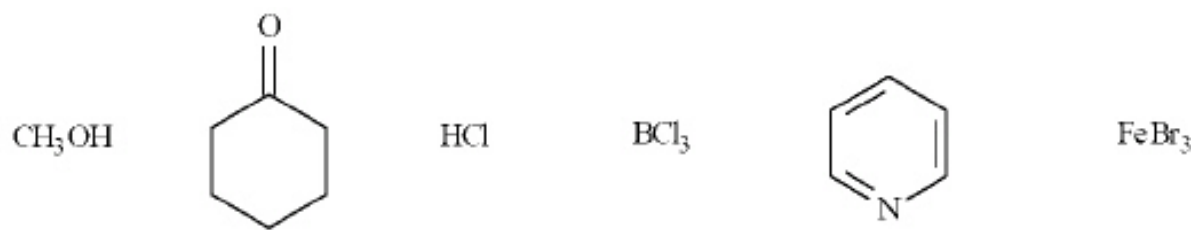
No, the reaction will not take place as written because the strongest acid reacts with the strongest base to give the weakest conjugate acid and the weakest conjugate base. **D** ($\text{pK}_a = 15.7$) is a stronger acid than **A** ($\text{pK}_a = 18$).

26. An acid with a low pK_a :

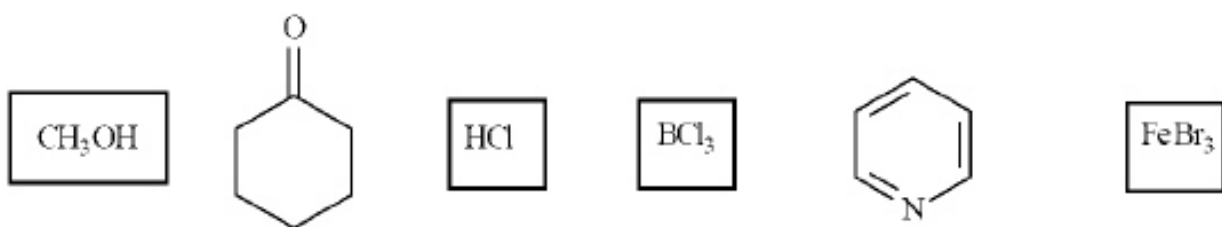
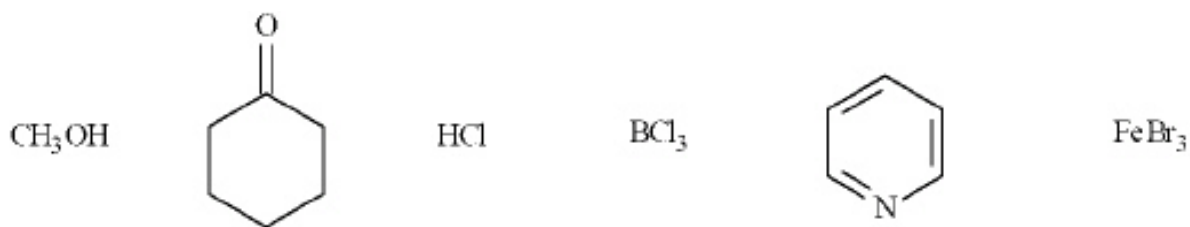
- is a weak acid
- is a strong acid
- has a weak conjugate base
- both b and c

d

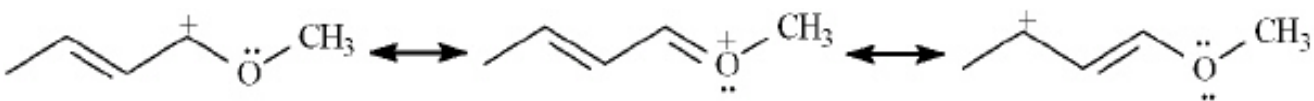
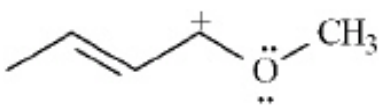
27. Circle all the Lewis bases in the group of compounds below.



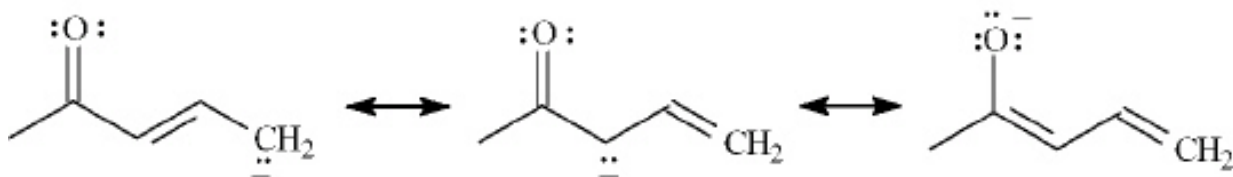
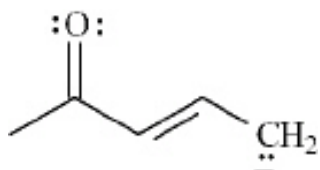
28. Put a box around all the Lewis acids in the group of compounds below.



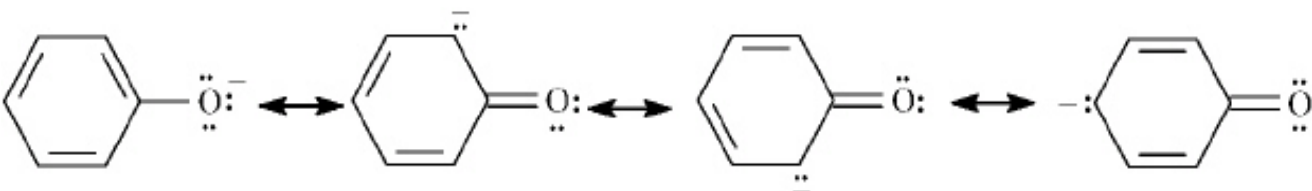
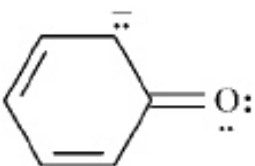
29. Draw *two* resonance structures for the species below.



30. Draw *two* resonance structures for the species below.

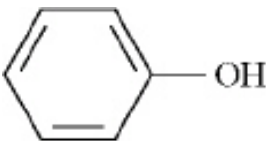


31. Draw *two* resonance structures for the species below.



32. **Exhibit 2-7**

Consider the acidity constants below to answer the following question(s).

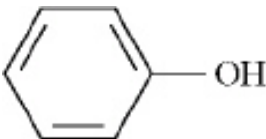
<u>ACID</u>	<u>STRUCTURE</u>	<u>pK_a</u>
phenol		10.00
ethanol	CH ₃ CH ₂ OH	16.00
water	HOH	15.74

Refer to Exhibit 2-7. Which acid will be almost completely deprotonated by NaOH?

phenol

33. **Exhibit 2-7**

Consider the acidity constants below to answer the following question(s).

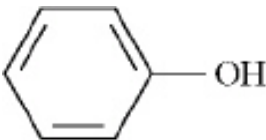
<u>ACID</u>	<u>STRUCTURE</u>	<u>pK_a</u>
phenol		10.00
ethanol	CH ₃ CH ₂ OH	16.00
water	HOH	15.74

Refer to Exhibit 2-7. Which acid has the *strongest* conjugate base?

Ethanol is the weakest acid (largest pK_a) so its conjugate base, ethoxide, CH₃CH₂O⁻, will be the strongest base.

34. **Exhibit 2-7**

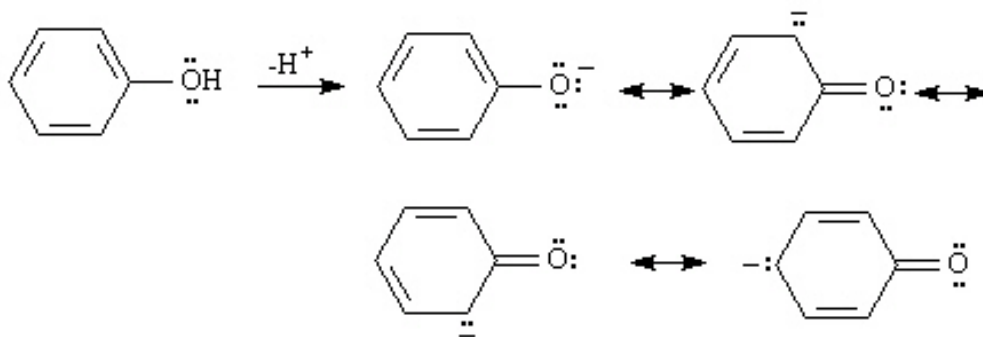
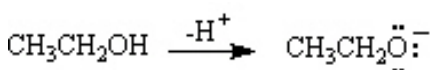
Consider the acidity constants below to answer the following question(s).

ACID	STRUCTURE	pK_a
phenol		10.00
ethanol	$\text{CH}_3\text{CH}_2\text{OH}$	16.00
water	HOH	15.74

Refer to Exhibit 2-7. Explain why phenol has a much lower pK_a than ethanol.

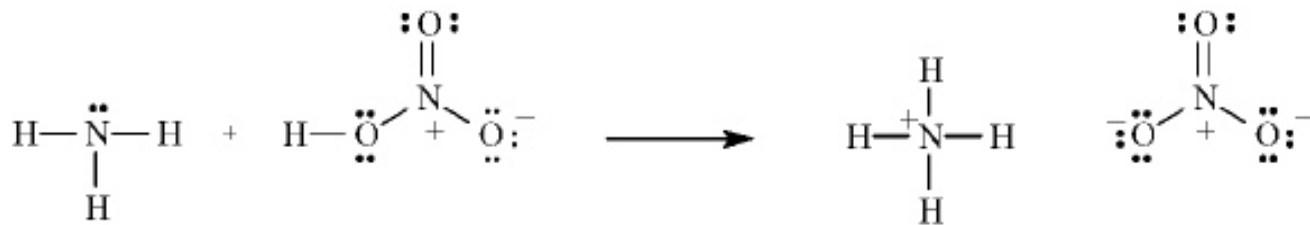
Phenol is more acidic (has a lower pK_a) than ethanol because the phenoxide anion is resonance stabilized by the pi electrons in the ring.

Ethoxide anion has no resonance stabilization. The negative charge is borne fully by oxygen.



35. **Exhibit 2-8**

Consider the reaction below to answer the following question(s).

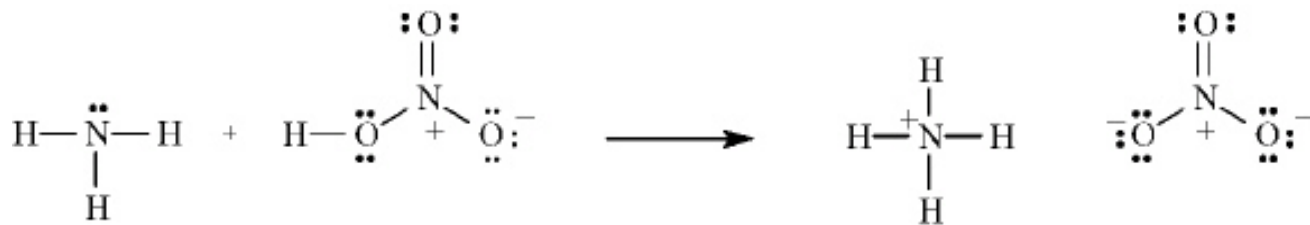


Refer to Exhibit 2-8. Using the curved arrow formalism, show the flow of electrons for this reaction.

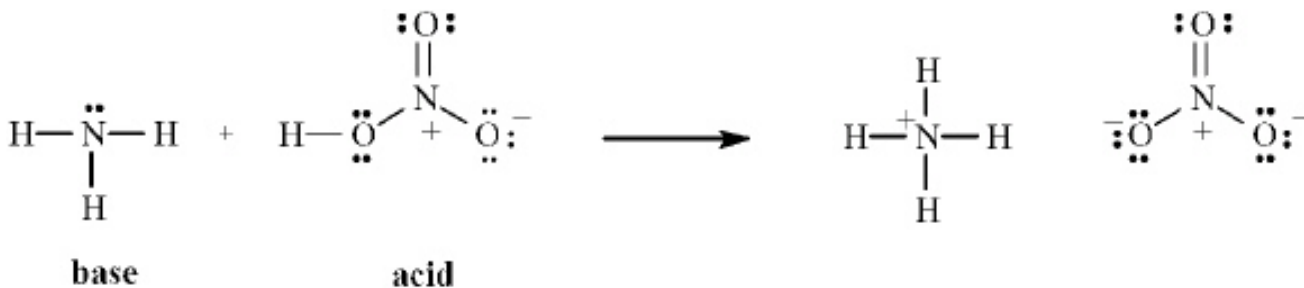


36. **Exhibit 2-8**

Consider the reaction below to answer the following question(s).

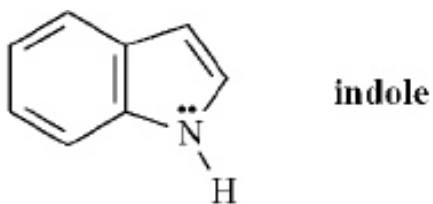


Refer to Exhibit 2-8. Label the acid and the base in the reaction.

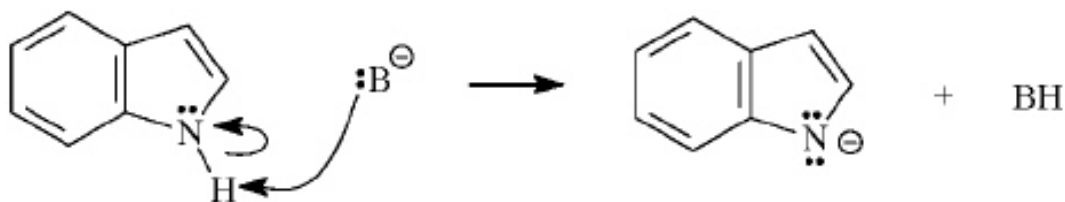


37. **Exhibit 2-9**

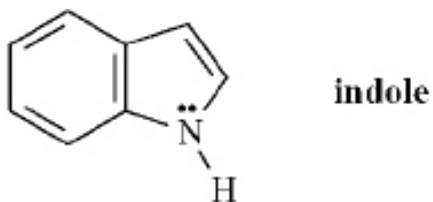
Indole is pleasant smelling in highly dilute solutions and has been used in perfumery. Use the structure of indole, below, to answer the following question(s).



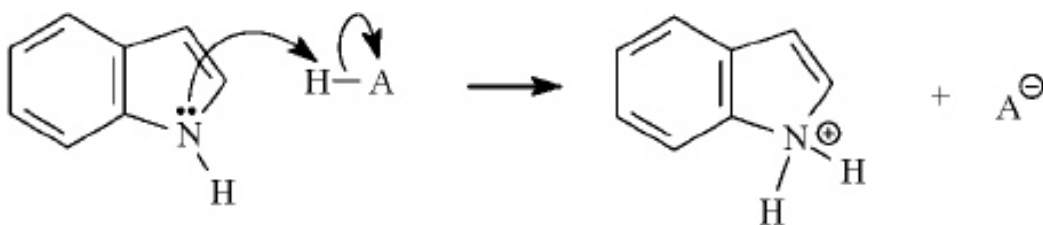
Refer to Exhibit 2-9. Indole can function as a Brønsted-Lowry acid in the presence of strong bases. Formulate a reaction, showing electron flow with arrows, that demonstrates this reactivity of indole.

38. **Exhibit 2-9**

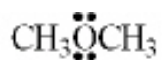
Indole is pleasant smelling in highly dilute solutions and has been used in perfumery. Use the structure of indole, below, to answer the following question(s).



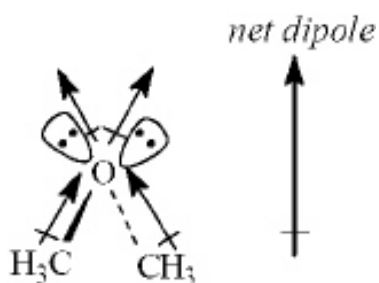
Refer to Exhibit 2-9. Indole can function as a Lewis base in the presence of strong acid. Formulate a reaction, showing electron flow with arrows, that demonstrates this reactivity of indole.



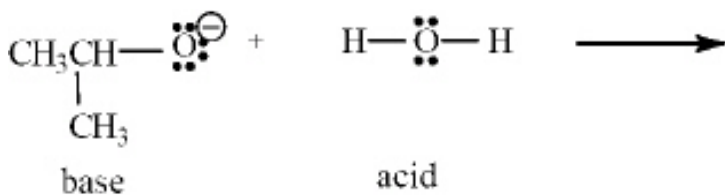
39. The condensed structure for dimethyl ether looks symmetrical. However, dimethyl ether has a dipole moment. Draw a structure that explains this and indicate the expected direction of the molecular dipole moment.



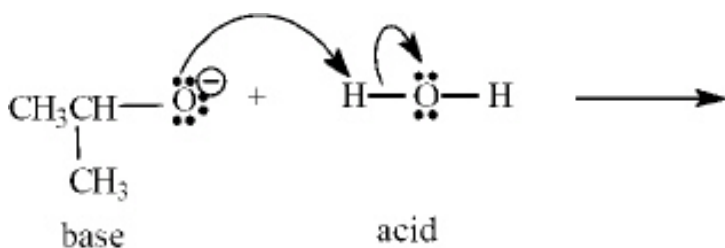
dimethyl ether



40. **Exhibit 2-10**
Consider the acid-base reaction below to answer the following question(s).

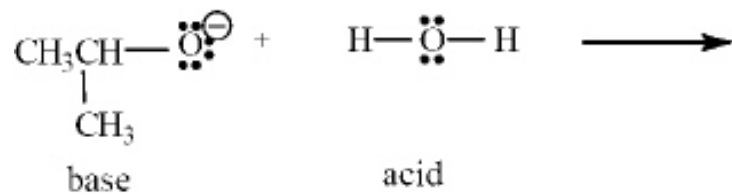


Refer to Exhibit 2-10. Using the curved arrow formalism, show the flow of electrons for this reaction.



41. **Exhibit 2-10**

Consider the acid-base reaction below to answer the following question(s).



Refer to Exhibit 2-10. Write the products of this Lewis acid - base reaction.

