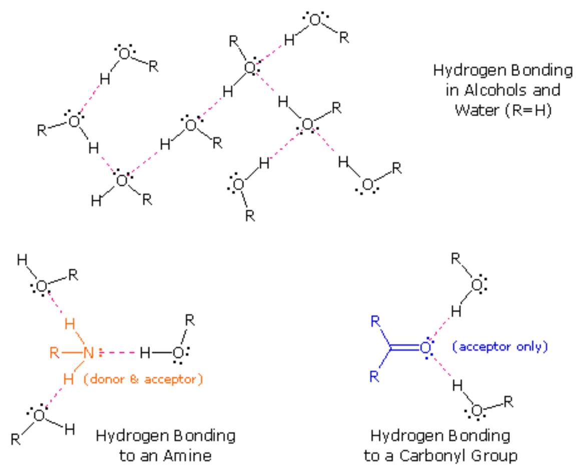
# 2.14: ORGANIC FUNCTIONAL GROUPS- H-BOND DONORS AND H-BOND ACCEPTORS

**Learning Objective**

- distinguish between organic compounds that are H-bond donors versus H-bond acceptors

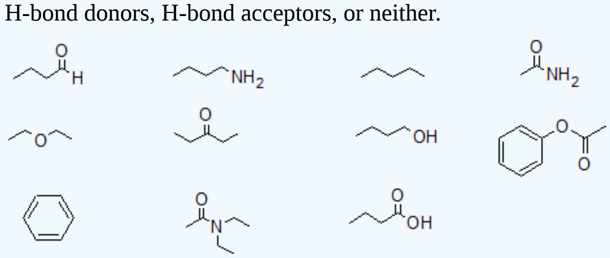
# H-bond donors vs H-bond acceptors

Compounds with H-bonding as their dominant intermolecular force (IMF) are BOTH H-bond donors and H-bond acceptors. They are H-bond donors because they have a highly polar hydrogen atom bonded to a strongly electronegative atom, primarily nitrogen, oxygen, or fluorine (NOF). Because there is an equivalent partial negative charge on the atom bonded to hydrogen (mostly NOF), this atom can accept H-bonds from another atoms. Since H-bond donors are ALWAYS H-bond acceptors, we simplify communication to "H-bond donor". There are two H-bonding interactions for H-bond donors. The strongly electronegative elements (primarily nitrogen, oxygen, and fluorine) will always form a relatively large partial negative charge when bonded with carbon. These elements can accept H-bonds when they are part of the organic molecule. In this situation, there is only one H-bonding interaction. The diagram below illustrates the similarities and differences between H-bond donors and H-bond acceptors. Water and alcohols may serve as both donors and acceptors, whereas ethers, aldehydes, ketones and esters can function only as acceptors. Similarly, primary and secondary amines are both donors and acceptors, but tertiary amines function only as acceptors.



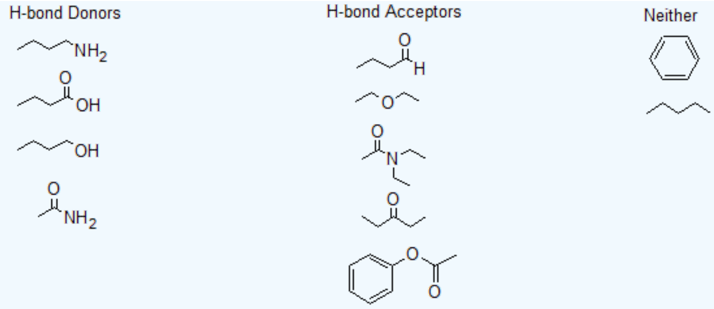

**Exercise**

1. Classify the compounds below as H-bond donors, H-bond acceptors, or neither.



**Answer**

1.

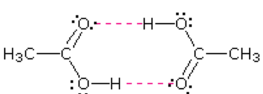



# Comparing Physical Properties of H-bond Donors vs H-bond Acceptors

Once we are able to recognize compounds that can exhibit intermolecular hydrogen bonding, the relatively high boiling points they exhibit become understandable. The data in the following table serve to illustrate this point.

| Compound | Formula | Mol. Wt. | Boiling Point | Melting Point |
|---|---|---|---|---|
| dimethyl ether | $CH_3OCH_3$ | 46 | –24ºC | –138ºC |
| ethanol | $CH_3CH_2OH$ | 46 | 78ºC | –130ºC |
| propanol | $CH_3(CH_2)_2OH$ | 60 | 98ºC | –127ºC |
| diethyl ether | $(CH_3CH_2)_2O$ | 74 | 34ºC | –116ºC |
| propyl amine | $CH_3(CH_2)_2NH_2$ | 59 | 48ºC | –83ºC |
| methylaminoethane | $CH_3CH_2NHCH_3$ | 59 | 37ºC | |
| trimethylamine | $(CH_3)_3N$ | 59 | 3ºC | –117ºC |
| ethylene glycol | $HOCH_2CH_2OH$ | 62 | 197ºC | –13ºC |
| acetic acid | $CH_3CO_2H$ | 60 | 118ºC | 17ºC |
| ethylene diamine | $H_2NCH_2CH_2NH_2$ | 60 | 118ºC | 8.5ºC |

Alcohols boil cosiderably higher than comparably sized ethers (first two entries), and isomeric 1º, 2º & 3º-amines, respectively, show decreasing boiling points, with the two hydrogen bonding isomers being substantially higher boiling than the 3º-amine (entries 5 to 7). Also, O–H---O hydrogen bonds are clearly stronger than N–H---N hydrogen bonds, as we see by comparing propanol with the amines.



As expected, the presence of two hydrogen bonding functions in a compound raises the boiling point even further. Acetic acid (the ninth entry) is an interesting case. A dimeric species, shown on the right, held together by two hydrogen bonds is a major component of the liquid state. If this is an accurate representation of the composition of this compound then we would expect its boiling point to be equivalent to that of a $C_4H_8O_4$ compound (formula weight = 120). A suitable approximation of such a compound is found in tetramethoxymethane, $(CH_3O)_4C$, which is actually a bit larger (formula weight = 136) and has a boiling point of 114ºC. Thus, the dimeric hydrogen bonded structure appears to be a good representation of acetic acid in the condensed state.

A related principle is worth noting at this point. Although the hydrogen bond is relatively weak (*ca.* 4 to 5 kcal per mole), when several such bonds exist the resulting structure can be quite robust. The hydrogen bonds between cellulose fibers confer great strength to wood and related materials. For additional information on this subject Click Here.