BOILING POINTS AND STRUCTURES OF HYDROCARBONS

The boiling points of organic compounds can give important clues to other physical properties and structural characteristics. A liquid boils when its vapor pressure is equal to the atmospheric pressure. Vapor pressure is determined by the kinetic energy of molecules. Kinetic energy is related to temperature and the mass and velocity of the molecules (K.E. = 1/2 mv^2). When the temperature reaches the boiling point, the average kinetic energy of the liquid particles is sufficient to overcome the forces of attraction that hold molecules in the liquid state.

Vapor pressure is caused by an equilibrium between molecules in the gaseous state and molecules in the liquid state. When molecules in the liquid state have sufficient kinetic energy they may escape from the surface and turn into a gas. Molecules with the most independence in individual motions achieve sufficient kinetic energy (velocities) to escape as gases at lower temperatures. The vapor pressure will be higher (more gas molecules are present) and therefore the compound will boil at a lower temperature.

BOILING POINT PRINCIPLE:

Molecules which strongly interact or bond with each other through a variety of intermolecular forces can not move easily or rapidly and therefore, do not achieve the kinetic energy necessary to escape the liquid state. Therefore, molecules with strong intermolecular forces will have higher boiling points. This is a consequence of the increased kinetic energy needed to break the intermolecular bonds so that individual molecules may escape the liquid as gases.

THE BOILING POINT CAN BE A ROUGH MEASURE OF THE AMOUNT OF ENERGY NECESSARY TO SEPARATE A LIQUID MOLECULE FROM ITS NEAREST NEIGHBORS TO FORM A GAS MOLECULE.

The Saturated Hydrocarbons, or Alkanes

Name	*Molecular Formula*	*Melting Point (^oC)*	*Boiling Point (^oC)*	*State at 25^oC*
methane	CH_4	-183	-164	gas
ethane	C_2H_6	-183	-89	
propane	C_3H_8	-190	-42	
butane	C_4H_{10}	-138	-0.5	
pentane	C_5H_{12}	-130	36	
hexane	C_6H_{14}	-95	69	
heptane	C_7H_{16}	-91	98	
octane	C_8H_{18}	-57	125	
nonane	C_9H_{20}	-51	151	liquid
decane	$C_{10}H_{22}$	-30	174	
undecane	$C_{11}H_{24}$	-25	196	
dodecane	$C_{12}H_{26}$	-10	216	
eicosane	$C_{20}H_{42}$	37	343	
triacontane	$C_{30}H_{62}$	66	450	solid

A variety of alkanes with the generic formula C_nH_{2n+2} are given in the table at the left with names, formulas, and physical properties. What is the general trend in the melting and boiling data? As the chain length (numbers of carbons) increases the melting and boiling points of the alkanes gradually increase for these compounds.

The reason that longer chain molecules have higher boiling points is that longer chain molecules become wrapped around and enmeshed in each other much like the strands of spaghetti. More energy is needed to separate them than short chain molecules which have only weak forces of attraction for each other.

QUES: Name some of the compounds in the table and state whether the compound will be a gas, liquid, or solid state at room temperature (20^oC). Hint: If the boiling point is below 20^oC, then the liquid has already boiled and is a gas.

What is the the boiling point trend in terms of the molecular weights of the compounds? At room temperature, the lighter alkanes are gases; the midweight alkanes are liquids; and the heavier alkanes are solids, or tars.