PROBLEM SOLVING:
RANKING MOLECULAR PROPERTIES BASED UPON INTERMOLECULAR FORCES

First of all, remember the following five kinds of forces found in bonds within and between molecules:					
Names and synonyms	**London forces** (instantaneous dipole)	**Permanent dipoles** Dipole-dipole	**Hydrogen bonding**	**Ionic bonds**	**Covalent bonds**
Energy	<1 kJ/mole	5kJ/mole	20 kJ/mole	200 kJ/mole	400 kJ/mole
Bond or attraction	intermolecular	intermolecular	intermolecular	inter- and intramolecular	intramolecular
Something interesting about the force	Non-polar molecules have no net dipole	Polar molecules have a net dipole	Strongest of intermolecular forces	Donate and accept electrons	Share electrons in a molecular bond
Rules for identification	ΔEN=0 or Σ dipole=0 (symmetry)	ΣΔEN 0	1. EN atom (EN > 3) 2. H attached to EN atom	ΔEN 2 to 3 ions from opposite ends of periodic table	ΔEN 0 to 1.5
Examples	Ar, N_2, CH_4, CH_3, OCH_3	NO, CH_3Cl, acetone	H_2O, CH_3OH, NH_3, HCl	NaCl, CaO, Al_2O_3	C-C, C-H, C-O, N-N
Physical properties	· Low BP · Low viscosity · High evaporation · Low surface tension	----------------->	· High BP · High viscosity · Low evaporation · High surface tension	· High melting point solids	

HOW TO ASSIGN FORCES IN FOUR EASY STEPS: The problem is to assign a molecule's intermolecular forces to one of the categories above. Follow the four-step procedure below as applied to assign forces to the following molecules:

N_2, CH_4, CH_3Cl, H_2O, and NaCl.

1. Draw Lewis dot structures.

2. Assign EN to each atom. To do this remember the following three rules for all atoms:
   - the second row ranges from 1 to 4 increasing by 0.5
   - H is out of place. It is EN=2.1
   - all the others elements are a few tenths smaller than the element above:

Li	**Be**	**B**	**C**	**N**	**O**	**F**
1.0	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**

3. Draw a vector representing the dipole moment between each bond reflecting the direction and magnitude of the electron density: i.e. ΔEN = 0 has no dipole, ΔEN 0.5 had a small dipole, ΔEN 2 had a large dipole.

4. Sum the vectors, ΣΔEN. Look for symmetry in the molecule that cancels out vectors.

Now rank properties based upon net dipole. Let's try some examples.

APPLYING FOUR STEPS TO FIVE SAMPLE MOLECULES TO RANK ON BASIS OF INTERMOLECULAR INTERACTIONS

Example 1. In **London forces,** if SDEN is zero or there is no net dipole, then the molecule is non-polar and has the weakest intermolecular forces.

N_2 ΔEN= 0? ____________ **CH_4** $\Sigma\Delta$EN= 0? _________

These compounds have low boiling points, low viscosity, high evaporation rate.

Example 2. In a **permanent dipole,** if $\Sigma\Delta EN \neq 0$, then compounds are polar and have intermediate intermolecular forces.

CH_3Cl $\Sigma\Delta$EN=0? _________

Properties: These compounds have intermediate boiling points, intermediate ΔH_{vap}, etc.

Example 3. In **hydrogen bonding** if: 1) there is an electronegative atom (EN >3 (N, O, F, Cl) and 2) a hydrogen atom is attached to an electronegative atom, then there are strong intermolecular forces.

H_2O Atom with large EN? ______ H adjacent to EN atom? _____

Properties: Water has a high boiling point, high ΔH_{vap}, high viscosity, low evaporation.

4. In **ion-ion interactions** if ΔEN 2 to 3 for cation from column Ia, IIa, IIIa combined with anion of an element in columns VIa and VIIa.

NaCl Column Ia, IIa, IIIa? _____ Column VIa and VIIa? _____ ΔEN= large? ______

Properties: These solids have very high melting points. Since these compounds are rarely in liquid form, we don't usually consider properties associated with liquids, like evaporation. But can you imagine how long someone would have to wait around to watch salt evaporate.