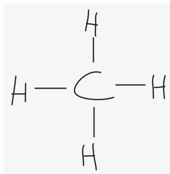
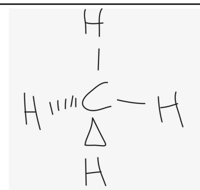
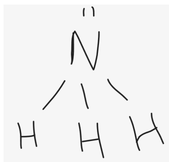
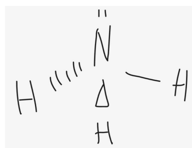
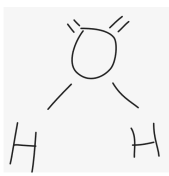
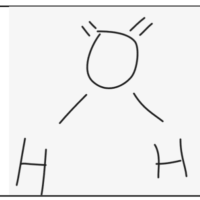
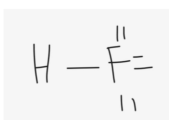
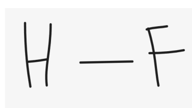
Relating Boiling Points to Intermolecular Forces

1. **Complete the table below using the top compound as the example for the group.**

Table 1: Background information of Hydrogen Compounds of Elements in Groups 14-17

Group	Hydrogen Compound	For the **first compound** in the group: Lewis Dot Diagram (draw bold molecule only)	3D Structural Diagram	State the shape	Intramolecular force	Intermolecular force	What is the difference between each of the molecules **within a group**?
14	**$CH_{4(g)}$** $SiH_{4(g)}$ $GeH_{4(g)}$ $SnH_{4(g)}$			Tetrahedral	C – 2.5 H – 2.1 2.5-2.1 = 0.4 **Covalent**	Just LDF	The only difference between the molecules in a group is that the central atom (in a group like 14, or 15) such as carbon or nitrogen, is getting bigger since it is getting more energy levels (a full layer of electrons). That means that the entire molecule will be getting bigger also.
15	**$NH_{3(g)}$** $PH_{3(g)}$ $AsH_{3(g)}$ $SbH_{3(g)}$			Trigonal Pyramidal	N – 3.0 H – 2.1 3.0-2.1 = 0.9 **Covalent**	LDF, Dipole-dipole, H-Bond	
16	**$H_2O_{(g)}$** $H_2S_{(g)}$ $H_2Se_{(g)}$ $H_2Te_{(g)}$			Bent	O – 3.5 H – 2.1 3.5-2.1 = 1.4 **Covalent**	LDF, Dipole-dipole, H-Bond	
17	**$HF_{(g)}$** $HCl_{(g)}$ $HBr_{(g)}$ $HI_{(g)}$			Linear	F – 4.0 H – 2.1 4.0-2.1 = 1.9 **Ionic**	LDF, Dipole-dipole, H-Bond	

2. Write a **thorough prediction** for the trend in boiling points **within** and **between** groups.
   Refer to shape, polarity, intramolecular forces, and intermolecular forces in your prediction.

Within groups, I predict that the boiling point will become higher down a group on the periodic table. My prediction is because when you go down the group, the atomic radius will get bigger. That will mean that there will be more opportunities for LDFs to happen.
I think that across groups on the periodic table, the boiling point will become higher because there will be more forces holding the atoms together such as the Dipole-dipole, H-Bond, and the Electronegativity difference will also increase (making the negative part of a polar molecule more and more negative, so the molecules will have a stronger attraction between them). Also, the AR of the atoms will be increasing slightly which will mean that there will be slightly more opportunities for LDFs to happen.

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3. **Complete the table below by calculating the total number of electrons in each compound.**

Table 2: Boiling Points of Hydrogen Compounds of Elements in Groups 14-17

Group	Hydrogen Compound	Boiling Point (ºC)	Number of Electrons per Molecule
14	$CH_{4(g)}$	-162	10
	$SiH_{4(g)}$	-112	18
	$GeH_{4(g)}$	-89	36
	$SnH_{4(g)}$	-52	54
15	$NH_{3(g)}$	-33	10
	$PH_{3(g)}$	-87	18
	$AsH_{3(g)}$	-55	36
	$SbH_{3(g)}$	-17	54
16	$H_2O_{(g)}$	100	10
	$H_2S_{(g)}$	-61	18
	$H_2Se_{(g)}$	-42	36
	$H_2Te_{(g)}$	-2	54
17	$HF_{(g)}$	20	10
	$HCl_{(g)}$	-85	18
	$HBr_{(g)}$	-67	36
	$HI_{(g)}$	-36	54

Graph

Observe the graph below. The graph is the number of total electrons per molecule versus the boiling point in degrees Celsius.

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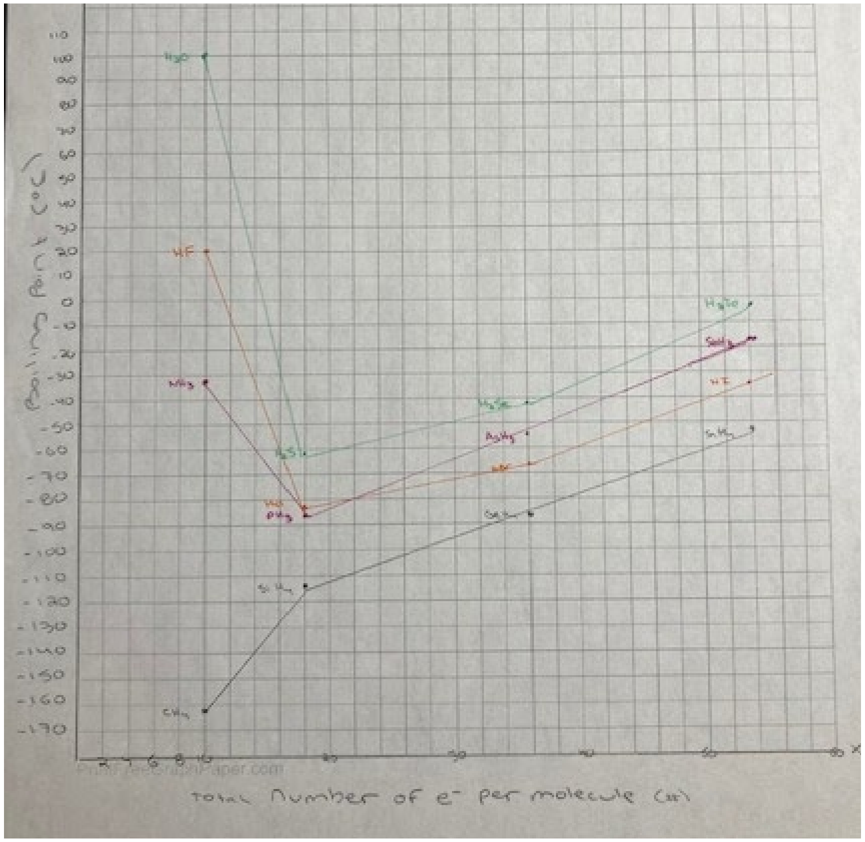

Analysis

a. State the general trend based on what you see on the graph?

The general trend in a group is as the number of electrons increases, the boiling point also increases.

b. Identify a **minimum** of 2 anomalies (unexpected evidence) on the graph.

Two of the anomalies are that within each of the groups (group 15, group 16, group 17) N, F, and O have significantly higher boiling points than the other elements in their group. The second anomaly is in group 14, Methane (CH_4) has a much lower boiling point than the other molecules in group 14.

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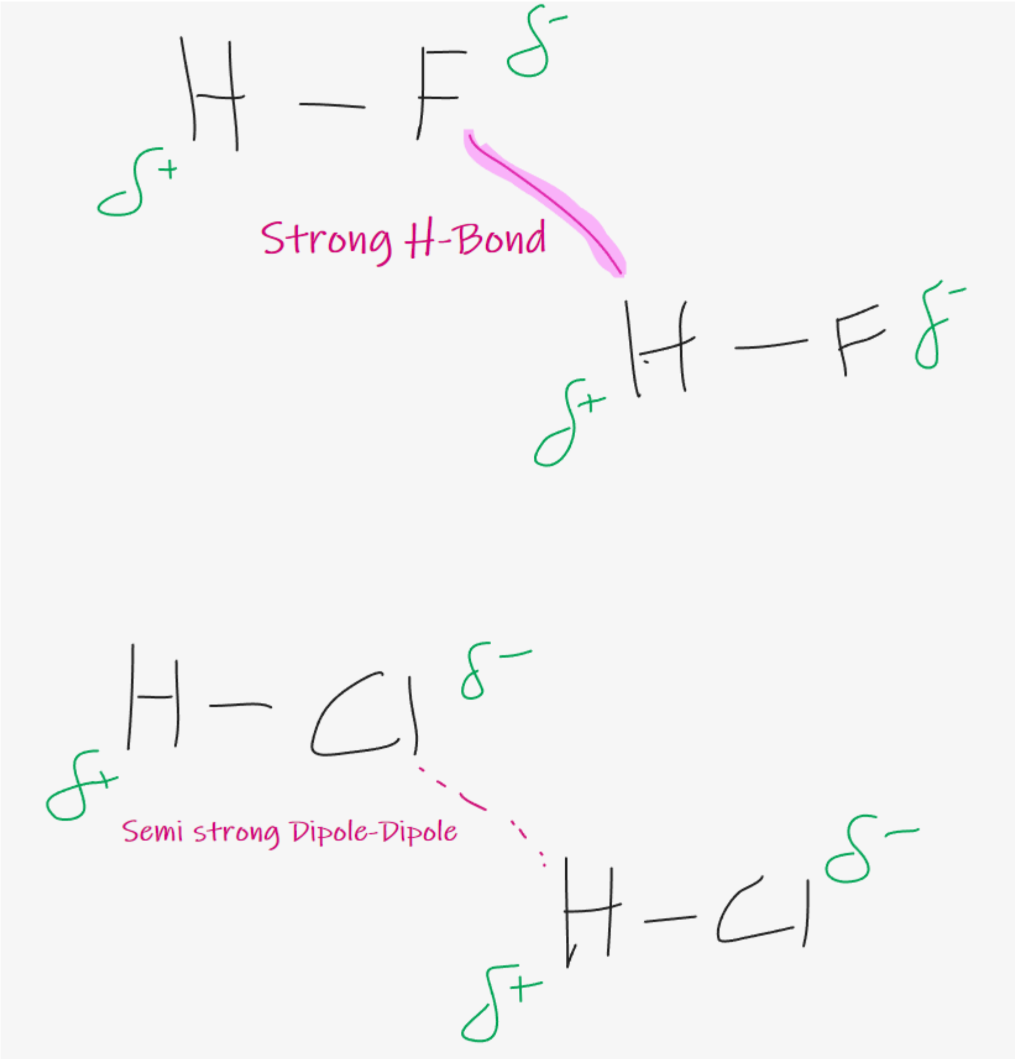
Discussion

c. Explain these anomalies



For the anomalies NH_3, H_2O, and HF, they have a higher boiling point because they have Nitrogen, Oxygen, and Fluorine in the compound which are all atoms that are used in H-Bonds. The reason that these atoms make very strong bonds is because they have a really strong electronegativity difference, so the delta negative part will be really negative, and the delta positive part will be really positive. That means that when they are attracted to another molecule, the attraction between the 2 molecules will be very strong. So, all of these 3 anomalies have LDF, Dipole-dipole, and H-Bond forces holding the molecules together while the other ones (in their group) only have LDF, and Dipole-dipole forces. The H-Bond force makes the attraction between multiple molecules much stronger, so it would take a lot more energy (heat in this example) to separate them. They need to be separated because solids are close together (and have the strongest

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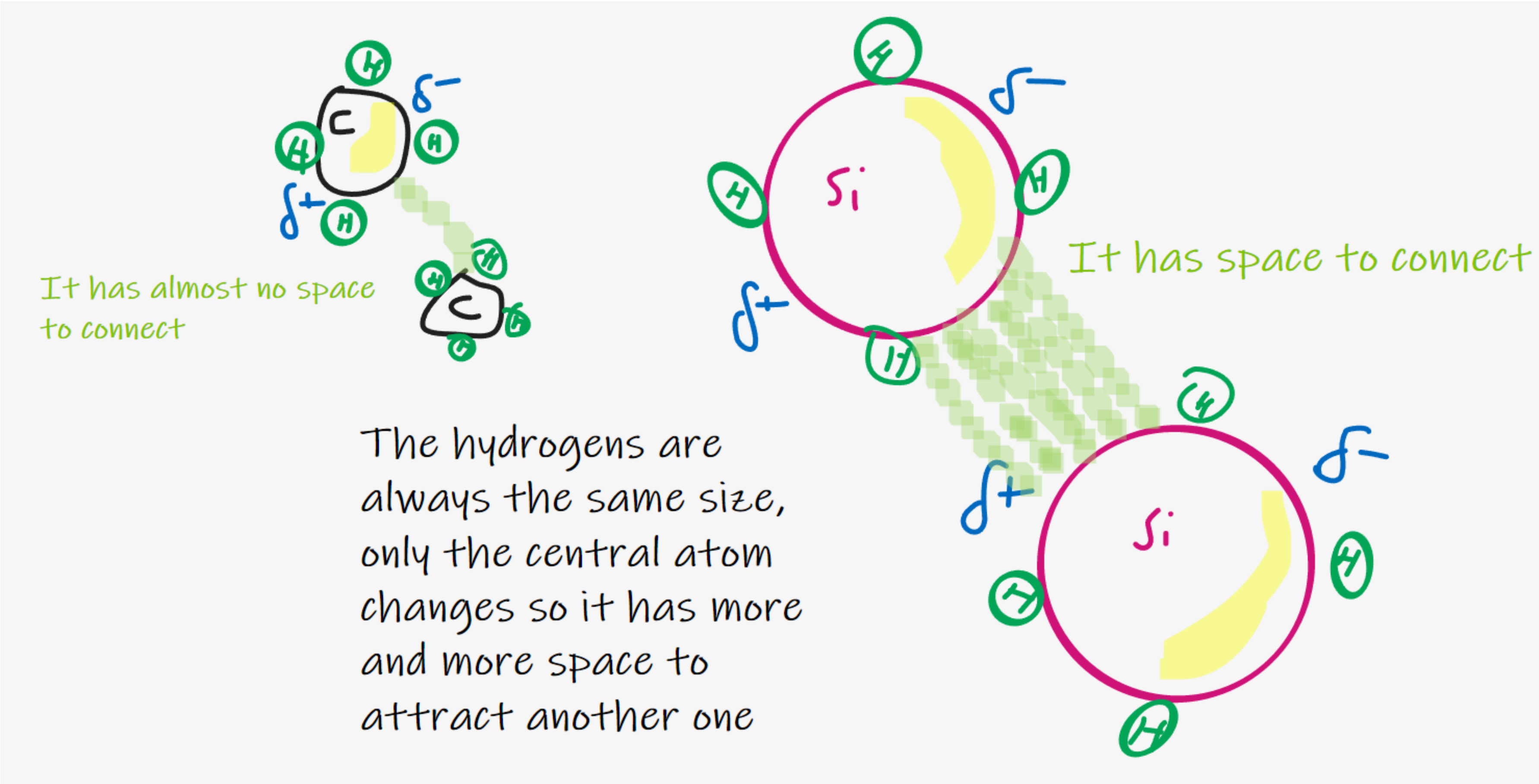
attraction), liquids are slightly further apart (and have slightly less attraction), and gasses have the molecules far apart (with the least attraction between molecules).



For the second anomaly, the methane (CH_4) has a much lower boiling point than the other molecules of its group (Si, Ge, and Sn). It makes sense that it would have a lower boiling point because there are less electrons available for LDFs, but it is an anomaly because the difference is much bigger than the others. The reason for that is because the carbon atom is so small that the hydrogen atoms are covering most of the carbon atom. Because of that, even if an LDF happens and the atom becomes polar for a split second, other molecules will not be able to get a good attraction to the original methane molecule (as can be seen on the left of the diagram) since the hydrogens are covering most of the carbon atom. With bigger center atoms (such as Silicon), it will be much easier for other molecules to be attracted to it when an LDF happens because there will physically be more space for it to attract to (as shown on the right of the diagram). There will be more space since the center atom is much bigger, but the hydrogen atoms will still be the exact same size.