Assignment - P.O.E.

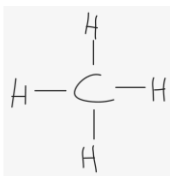
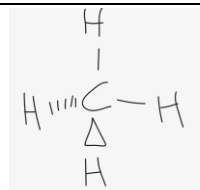
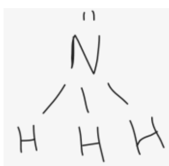
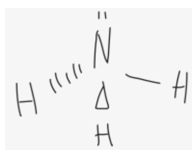
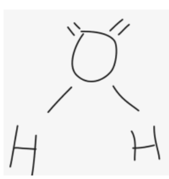
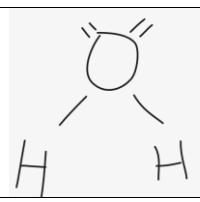
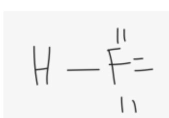
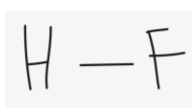
Relating Boiling Points to Intermolecular Forces

In all liquids, intermolecular forces are present between molecules/compounds. These forces, however, become negligible above boiling point when the substance becomes a gas. During the boiling, intermolecular forces must be overcome by the addition of energy. The temperature at which a liquid boils reflects the strength of its intermolecular forces. **A high boiling point means that more energy has been added to separate the molecules, and thus the intermolecular forces must be strong.**

In this assignment use the provided data to explore the trend in boiling points of hydrogen compounds of elements in groups 14-17.

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					What is the difference between each of the molecules **within a group**?
		Lewis Dot Diagram (draw bold molecule only)	3D Structural Diagram	State the shape	Intramolecular force	Intermolecular force	
14	$\mathbf{CH_{4(g)}}$ $SiH_{4(g)}$ $GeH_{4(g)}$ $SnH_{4(g)}$			Tetrahedral	C – 2.5 H – 2.1 2.5-2.1 = 0.4 **Covalent**	Just LDF	
15	$\mathbf{NH_{3(g)}}$ $PH_{3(g)}$ $AsH_{3(g)}$ $SbH_{3(g)}$			Trigonal Pyramidal	N – 3.0 H – 2.1 3.0-2.1 = 0.9 **Covalent**	LDF, Dipole-dipole, H-Bond	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.
16	$\mathbf{H_2O_{(g)}}$ $H_2S_{(g)}$ $H_2Se_{(g)}$ $H_2Te_{(g)}$			Bent	O – 3.5 H – 2.1 3.5-2.1 = 1.4 **Covalent**	LDF, Dipole-dipole, H-Bond	
17	$\mathbf{HF_{(g)}}$ $HCl_{(g)}$ $HBr_{(g)}$ $HI_{(g)}$			Linear	F – 4.0 H – 2.1 4.0-2.1 = 1.9 **Ionic**	LDF, Dipole-dipole, H-Bond	

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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.

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

For example:
Carbon has 6 electrons total and hydrogen has 1 electron. There are four hydrogens. The total number of electrons is 10

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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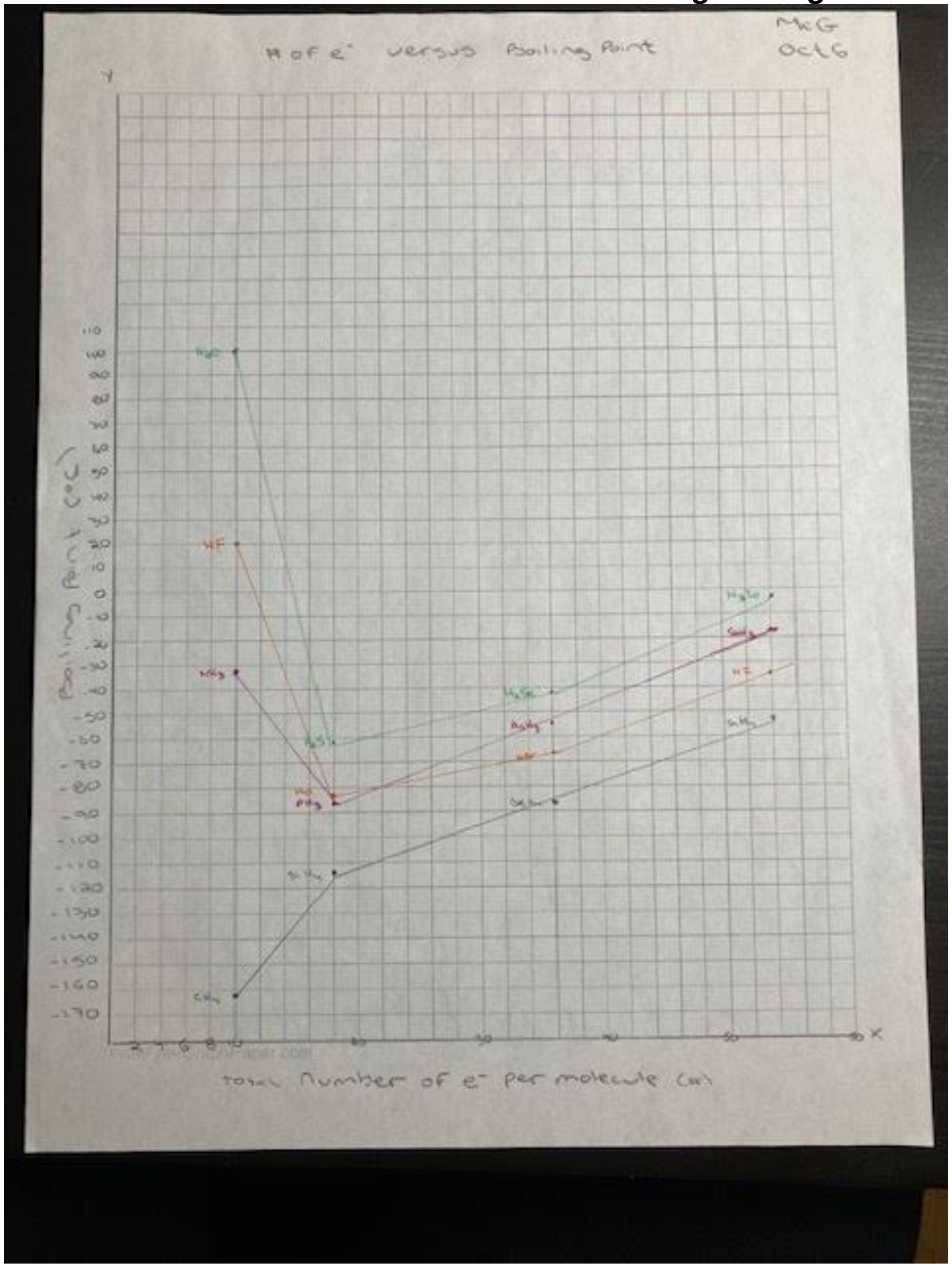

Analysis

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

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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. Note: an anomaly is something you did not predict.

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.

Discussion

c. Explain these anomalies using your knowledge of shape, polarity, lone pairs, electronegativity, and include details about intermolecular forces.

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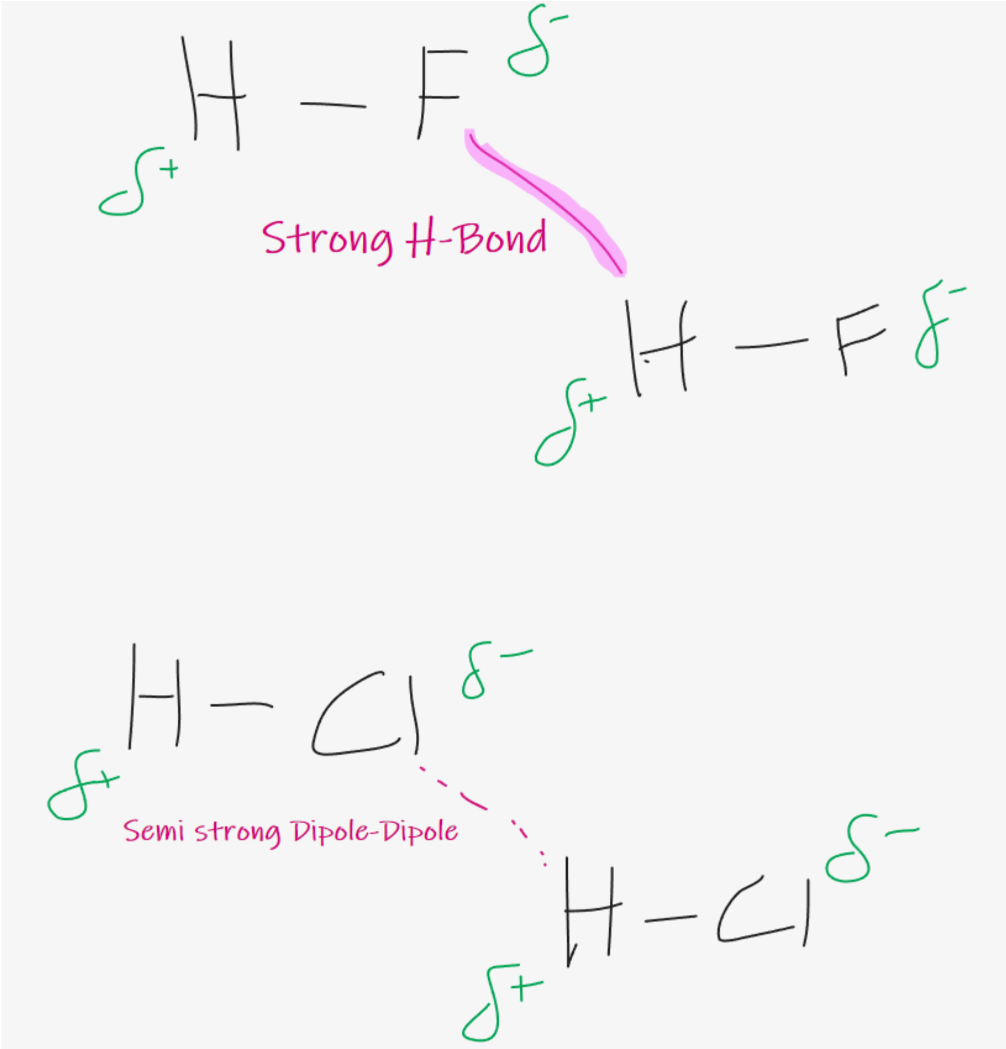

For the anomalies NH_3, H_2O, and HF, they have a higher boiling point because they have Nitrogen, Oxygen, and Fluorine in the compound which are all atoms that are used in H-Bonds. The reason that these atoms make very strong bonds is because they have a really strong electronegativity difference, so 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 attraction), liquids are slightly further apart (and have slightly less attraction), and gasses have the molecules far apart (with the least attraction between molecules).

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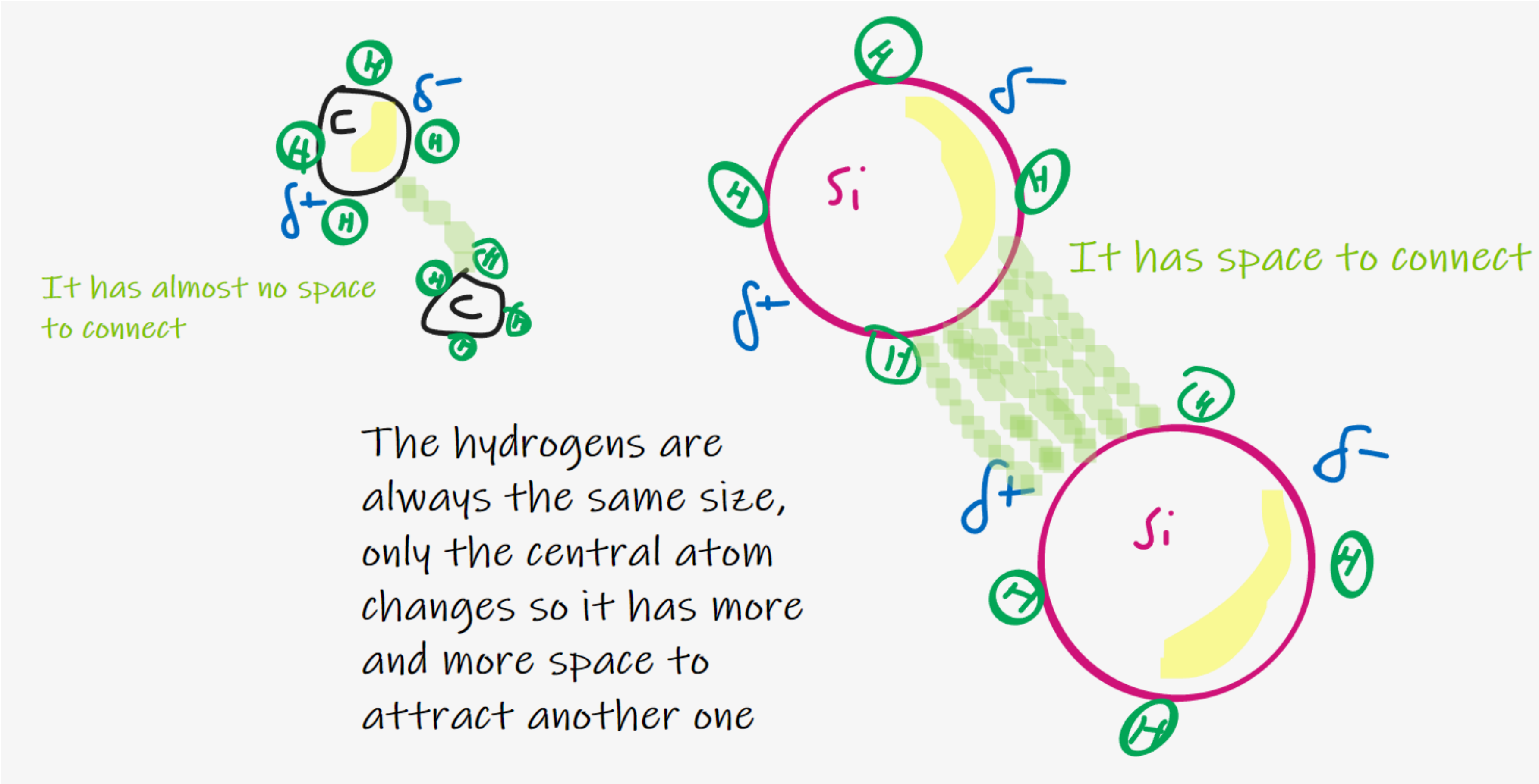

For the second anomaly, the methane (CH_4) has a much lower boiling point than the other molecules of its group (Si, Ge, and Sn). It makes sense that it would have a lower boiling point because there are less electrons available for LDFs, but it is an anomaly because the difference is much bigger than 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.

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Curriculum Expectation
B3. demonstrate an understanding of periodic trends in the periodic table and how elements combine to form chemical bonds.

Rubric

Expectation	R	Level 1	Level 2	Level 3	Level 4
B2. investigate physical and chemical properties of elements and compounds, and use various methods to visually represent them **Table 1 + Analysis**		Student uses gr 10 terminology Limited accuracy in illustrating the lewis structures	Student uses some grade 11 terminology, or uses it but used incorrectly Student somewhat accurately illustrates the lewis structures, compounds involved, with a few minor mistakes or one major error	Student uses grade 11 terminology correctly and consistently *electron pull, electron shielding, atomic radius, electronegativity, electron affinity, ionization energy, intermolecular forces, shape, polarity, lone pairs* Student accurately illustrates the lewis structures for all compounds, and correctly identifies intra/inter forces (minor errors)	Student uses most relevant grade 11 terminology correctly and consistently Student accurately illustrates the lewis structures for all compounds, and correctly identifies intra/inter forces (no errors). Shows the dipole moment
B3. demonstrate an understanding of periodic trends in the periodic table **Prediction and Discussion**		Limited detail; multiple major errors present Simply states properties	Some detail; multiple minor errors or one major error that demonstrates a misunderstanding of concepts	Student explains the difference in physical properties in considerable detail *(connects to intra/interforces)* *Uses a few different ways to explain prediction: lone pairs, E.N, shape, intermolecular forces	Student explains the difference in physical properties in thorough detail *(connects to intra/interforces)* Thorough detail, extension makes insightful connections