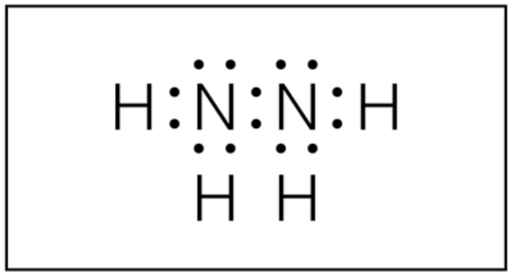
Question 5

Hydrazine is an inorganic compound with the formula N_2H_4.

(a) In the box below, complete the Lewis electron-dot diagram for the N_2H_4 molecule by drawing in all the electron pairs.



The correct Lewis diagram has single bonds between each pair of atoms and a lone pair of electrons on each N atom (a total of 14 e^-).	1 point is earned for the correct Lewis diagram.

(b) On the basis of the diagram you completed in part (a), do all six atoms in the N_2H_4 molecule lie in the same plane? Explain.

No, they do not. The molecular geometry surrounding both nitrogen atoms is trigonal pyramidal. Therefore the molecule as a whole cannot have all the atoms in the same plane.	1 point is earned for a correct answer with a valid explanation.

(c) The normal boiling point of N_2H_4 is 114°C, whereas the normal boiling point of C_2H_6 is −89°C. Explain, in terms of the intermolecular forces present in each liquid, why the boiling point of N_2H_4 is so much higher than that of C_2H_6.

N_2H_4 is a polar molecule with London dispersion forces, dipole-dipole forces, and hydrogen bonding between molecules, whereas C_2H_6 is nonpolar and only has London dispersion forces between molecules. It takes more energy to overcome the stronger IMFs in hydrazine, resulting in a higher boiling point.	1 point is earned for correct reference to the two different types of IMFs. 1 point is earned for a valid explanation based on the relative strengths of the IMFs.

Question 5 (continued)

(d) Write a balanced chemical equation for the reaction between N_2H_4 and H_2O that explains why a solution of hydrazine in water has a pH greater than 7.

$N_2H_4 + H_2O \rightarrow N_2H_5^+ + OH^-$	1 point is earned for a valid equation.

N_2H_4 reacts in air according to the equation below.

$$N_2H_4(l) + O_2(g) \rightarrow N_2(g) + 2\ H_2O(g) \qquad \Delta H° = -534 \text{ kJ mol}^{-1}$$

(e) Is the reaction an oxidation-reduction, acid-base, or decomposition reaction? Justify your answer.

The reaction is an oxidation-reduction reaction. The oxidation state of N changes from −2 to 0 while that of O changes from 0 to −2.	1 point is earned for the correct choice with a valid justification.

(f) Predict the sign of the entropy change, ΔS, for the reaction. Justify your prediction.

The entropy change for the reaction is expected to be positive. There are three moles of gas produced from one mole of liquid and one mole of gas. The net increase of two moles of gas results in a greater entropy of products compared to the entropy of reactants.	1 point is earned for the correct prediction with a valid justification.

(g) Indicate whether the statement written in the box below is true or false. Justify your answer.

The large negative $\Delta H°$ for the combustion of hydrazine results from the large release of energy that occurs when the strong bonds of the reactants are broken.

The statement is false on two counts. First, energy is released not when bonds are broken, but rather when they are formed. Second, the bonds in the reactants are relatively weak compared to the bonds in the products.	1 point is earned for correctly identifying the statement as false along with a valid justification.

 5A1

Answer Question 5 and Question 6. The Section II score weighting for these questions is 15 percent each.

Your responses to these questions will be scored on the basis of the accuracy and relevance of the information cited. Explanations should be clear and well organized. Examples and equations may be included in your responses where appropriate. Specific answers are preferable to broad, diffuse responses.

5. Hydrazine is an inorganic compound with the formula N_2H_4.

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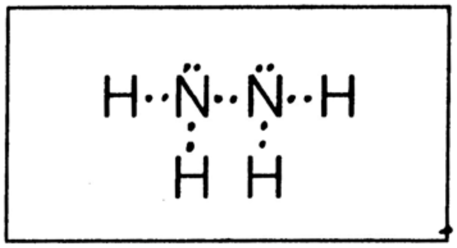

(b) On the basis of the diagram you completed in part (a), do all six atoms in the N_2H_4 molecule lie in the same plane? Explain.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

b. No. Each N atom has an AX_3E, or trigonal pyramidal shape. The nonbonding e^- pair pushes the other e^-'s involved in bonds away, resulting in a 3-dimensional molecule

c. In N_2H_4, there are dispersion forces, dipole forces, and hydrogen bonds. The hydrogen bonds between H-N especially make stronger attractions between the molecules. Being so much harder to break, these H-bonds account for the high BP of N_2H_4. On the other hand, C_2H_6 only has dispersion forces and induced dipoles. These intermolecular forces are much weaker than H-bonds ∴ the BP of the molecule is lower.

d.

$$N_2H_4 + H_2O(l) \rightarrow N_2H_5^+ + OH^-$$

The N_2H_4 molecule accepts a H^+ ion, making it a Bronsted-Lowry base. It also produces OH^- in water, making the pH greater than 7.

e. This rxn is an oxidation-reduction rxn because N is ~~reduced~~ oxidized (charge from -2 to 0) and O is reduced (from 0 to -2).

f. ΔS would be positive because there are more moles of gas in the products than there are in the reactants (3 mol in prod. > 1 mol in react.)

g. This is false because if they were extremely strong bonds, they would actually require energy to break rather than release it. The negative $\Delta H°$ results from the E released when the bonds of the products are formed.

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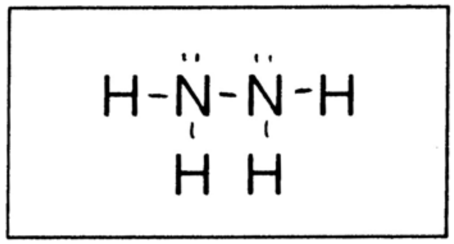

☺ 2x8 4x2 24
Have 2x5 4x1 14
5 bond
7 pairs
2LP

(b) On the basis of the diagram you completed in part (a), do all six atoms in the N_2H_4 molecule lie in the same plane? Explain.

(c) The normal boiling point of N_2H_4 is 114°C, whereas the normal boiling point of C_2H_6 is −89°C. Explain, in terms of the intermolecular forces present in <u>each</u> liquid, why the boiling point of N_2H_4 is so much higher than that of C_2H_6.

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(e) Is the reaction an oxidation-reduction, acid-base, or decomposition reaction? Justify your answer.

(f) Predict the sign of the entropy change, ΔS, for the reaction. Justify your prediction.

(g) Indicate whether the statement written in the box below is true or false. Justify your answer.

The large negative ΔH° for the combustion of hydrazine results from the large release of energy that occurs when the strong bonds of the reactants are broken.

b) all atoms do not lie in the same plane because each N atom has four things around it, making two trigonal pyramidal structures.

c) the boiling point of N_2H_4 is so much higher because N atoms can participate in hydrogen bonding, so each N_2H_4 molecule is attracted to each other and harder to break up. C_2H_6, however, cannot participate in hydrogen bonding because C atoms do not H bond, so the only force in C_2H_6 is van der waals because dipoles cancel since C_2H_6 is symmetrical.

d) $N_2H_4 + 2H_2O \rightleftharpoons N_2H_6 + 2OH^-$

N_2H_4 accepts two protons from water making the solution basic.

e) this is a redox reaction because N in N_2H_4 goes from 2^- to 0 in $N_2(g)$ and O_2 goes from 0 to 2^- in H_2O.

f) ΔS will be positive because there are more moles of products than reactants and because a liquid and a gas form two gases, and gases have more entropy than liquids.

g) the statement is false because the bonds of the reactants are not strong. In exothermic reactions, the reactants are more easily broken than the products, so reactants bonds are weaker. Plus, N_2, a product, has a triple bond which is the hardest to break.

 5C 1

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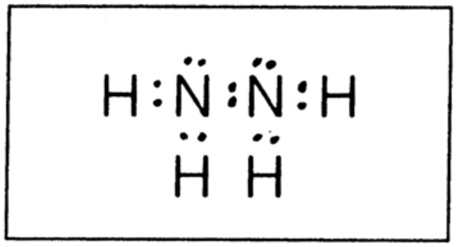

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   (e) Is the reaction an oxidation-reduction, acid-base, or decomposition reaction? Justify your answer.

   (f) Predict the sign of the entropy change, ΔS, for the reaction. Justify your prediction.

   (g) Indicate whether the statement written in the box below is true or false. Justify your answer.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 5

b) No, considering the lone pairs of electrons, the geometry of the molecule would not allow for a singular plane.

c) Between N_2H_4 and C_2H_6, there are two forces at work. First, the carbons are less polar to the hydrogens than the nitrogens are. Secondly, on the C_2H_6 atom, there are more hydrogens that can be broken off with less ~~force~~, releasing more vaporized C_2H_6.

d) $N_2H_{4(aq)} + 2H_2O_{(l)} \rightarrow 2NH_{3(aq)} + 2OH^-_{(aq)}$; Since there is a concentration of OH^- ions in the solution, the pH increases into a basic solution, which is above 7.

▶ $N_2H_{4(l)} + O_{2(g)} \rightarrow N_{2(g)} + 2H_2O_{(g)}$; $\Delta H° = -534$ kJ·mol^{-1}

e) This reaction is an oxidation-reduction reaction, as can be seen as the N ion goes from a -2 charge to zero charge and the O_2 goes from a zero charge to a -2 charge.

f) ΔS for this reaction will be positive since it goes from a liquid and gas (with limited microstates) to two separate gases.

g) This statement is false. Energy is not released when bonds are broken; rather, it takes energy to break bonds.

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Question 5

Overview

This question asked students to complete the Lewis diagram for the N_2H_4 molecule in part (a). Part (b) asked students to determine, based on their diagram, whether or not all six atoms were on the same plane and to justify their answer. Part (c) gave students the boiling points for N_2H_4 and C_2H_6 and asked them to explain the difference in boiling points in terms of the intermolecular forces in each liquid. In part (d) students wrote a balanced chemical equation for the reaction between N_2H_4 and water to explain a pH greater than 7. Part (e) gave students a balanced chemical equation for hydrazine reacting in air and asked them to identify the type of reaction and justify their answer. In part (f) students were asked to refer to the equation provided in part (e) and predict the sign of the entropy change, with justification. In part (g) students were given a statement regarding energy and the breaking of bonds and were asked to justify whether the statement was true or false.

Sample: 5A
Score: 8

This response earned all 8 available points. Part (a) earned 1 point for a correct structure. Part (b) earned 1 point for the correct identification of molecular geometry. Part (c) earned 2 points for identifying the predominant intermolecular forces in both N_2H_4 and C_2H_6 and including a comparison of strength related to boiling points. Part (d) earned 1 point for the correctly balanced equation. Part (e) earned 1 point for correctly identifying the reaction as oxidation-reduction and giving the correct oxidation state changes of nitrogen and oxygen. Part (f) earned 1 point for the correct sign for entropy change with appropriate justification. Part (g) earned 1 point for noting that energy is required to break bonds and that energy is released when bonds are formed.

Sample: 5B
Score: 6

Part (c) earned no points for identification of intermolecular forces when the only force for C_2H_6 was identified as Van der Waals. Part (d) earned no point for an incorrect equation.

Sample: 5C
Score: 4

Part (b) earned no point for stating the presence of lone pairs of electrons without an explanation of how the shape is altered by the electrons. Part (c) earned no points because the student describes intramolecular forces and bonds being broken in order for the liquids to vaporize. Part (d) earned no point for an incorrect equation.