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.

```
  H : N : N : H
     \   /   \   /
      H       H
```

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.
(d) Write a balanced chemical equation for the reaction between $\text{N}_2\text{H}_4$ and $\text{H}_2\text{O}$ that explains why a solution of hydrazine in water has a pH greater than 7.

\[
\text{N}_2\text{H}_4 + \text{H}_2\text{O} \rightarrow \text{N}_2\text{H}_5^+ + \text{OH}^- 
\]

1 point is earned for a valid equation.

$\text{N}_2\text{H}_4$ reacts in air according to the equation below.

\[
\text{N}_2\text{H}_4(l) + \text{O}_2(g) \rightarrow \text{N}_2(g) + 2 \text{H}_2\text{O}(g) \quad \Delta H^\circ = -534 \text{ kJ mol}^{-1}
\]

(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 $\text{N}$ changes from $-2$ to $0$ while that of $\text{O}$ 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, $\Delta S$, 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 $\Delta H^\circ$ 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.