1. A growing plant is an example of decreasing entropy. Small molecules like CO$_2$ and H$_2$O are built into complex but orderly arrangements of macromolecules. Which one of the following statements applies?
   (a) The second law of thermodynamics is violated by living processes.
   (b) Plant growth is so complex that the laws of thermodynamics cannot be applied.
   (c) The second law of thermodynamics is not being violated because the entropy of the plant’s surroundings is increasing.
   (d) The second law of thermodynamics is not being violated because the entropy of the plant’s surroundings is decreasing.
   (e) None of the above.

2. Suppose that we are examining a biological polymer that undergoes a reaction
   polymer $\rightarrow$ product
   and we are able to determine that at a given temperature the reaction is spontaneous
   and endothermic. What does this imply about the structure of the product?
   (a) Nothing.
   (b) The product is a less ordered structure than the polymer.
   (c) The product is a more ordered structure than the polymer.
   (d) The heat of formation of the polymer is more positive than that of the product.
   (e) Since the process is endothermic, the reaction cannot occur and is not spontaneous. The data are suspect.

3. Assume that the enthalpy of fusion of ice is 6.030 kJ mol$^{-1}$ and does not vary
   appreciably over the temperature range -10$^\circ$C to +10 $^\circ$C. If 1.00 mole of ice at 0 $^\circ$C is
   melted by heat supplied from the surroundings at 10 $^\circ$C, what is the entropy change in
   the surroundings in J K$^{-1}$?
   (a) +22.1              (b) +21.3                 (c) +0.603                 (d) -21.3               (e) -22.1

4. Choose the correct statement.
   (a) Exothermic reactions are always spontaneous.
   (b) Free energy is independent of temperature.
   (c) A reaction which exhibits a negative value of $\Delta S$ cannot be spontaneous.
   (d) At constant $P$ and $T$, a decrease in free energy ensures an increase in the entropy
       of the system.
   (e) None of the above statements is true.

5. For a particular chemical reaction, $\Delta H = 5.5$ kJ and $\Delta S = -25$ J K$^{-1}$. Under what
   temperature conditions is the reaction spontaneous?
   (a) $T < -220$ K                       (b) $T < 220$ K                          (c) $T > 220$ K
   (d) The reaction is spontaneous at all temperatures.
   (e) The reaction is not spontaneous at any temperature.

6. Processes can be characterised by the sign of $\Delta H$ and $\Delta S$, as in the table.
   Process | $\Delta H$ | $\Delta S$
   --------|-----------|--------
   1       | -         | +      
   2       | +         | -      
   3       | -         | -      
   4       | +         | +      

   Which of the processes are definitely spontaneous, and which are possibly spontaneous
   for processes at constant $T$ and $P$?
   (a) Definitely (1), possibly (2)
   (b) Definitely (1) & (3), possibly (4)
   (c) Definitely (3), possibly (1) & (2)
   (d) Definitely (4), possibly (1)
   (e) Definitely (1), possibly (3) & (4)
7. Consider the reaction
\[ 2\text{N}_2\text{O}_5 (g) \rightleftharpoons 4\text{NO}_2 (g) + \text{O}_2 (g) \]
at 25°C, for which the following data are relevant:

<table>
<thead>
<tr>
<th>Substance</th>
<th>ΔH° / kJ mol⁻¹</th>
<th>S° / J K⁻¹ mol⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂O₅ (g)</td>
<td>11</td>
<td>356</td>
</tr>
<tr>
<td>NO₂ (g)</td>
<td>33</td>
<td>240</td>
</tr>
<tr>
<td>O₂ (g)</td>
<td>0</td>
<td>205</td>
</tr>
</tbody>
</table>

Which of the following is true for this reaction?
(a) Both ΔH° and ΔS° favour the reaction’s spontaneity.
(b) Both ΔH° and ΔS° oppose the reaction's spontaneity.
(c) ΔH° favours the reaction but ΔS° opposes it.
(d) ΔH° opposes the reaction but ΔS° favours it.
(e) The reaction cannot occur at room temperature.

8. Consider the freezing of liquid water at -10°C. For this process what are the values or signs for ΔH, ΔS and ΔG?

<table>
<thead>
<tr>
<th>ΔH</th>
<th>ΔS</th>
<th>ΔG</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
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<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

9. Calculate ΔG° for the reaction
\[ \text{H}_2\text{O (g)} + \frac{1}{2}\text{O}_2 (g) \rightleftharpoons \text{H}_2\text{O}_2 (g) \]
at 600 K using the following data.

\[ \text{H}_2 (g) + \text{O}_2 (g) \rightleftharpoons \text{H}_2\text{O}_2 (g) \quad K_p = 2.3 \times 10^6 \text{ atm}^{-1} \text{ at 600 K} \]
\[ 2\text{H}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2\text{H}_2\text{O} (g) \quad K_p = 1.8 \times 10^{37} \text{ atm}^{-1} \text{ at 600 K} \]

(a) +140 kJ mol⁻¹
(b) -220 kJ mol⁻¹
(c) -290 kJ mol⁻¹
(d) -350 kJ mol⁻¹
(e) +290 kJ mol⁻¹

10. When reactants and products are all in their standard states, which of the following must be true?
(a) ΔG = 0
(b) ΔG = ΔG°
(c) Q = 1
(d) ΔG = ΔG° and Q = 1
(e) ΔG = 0 and ΔG = ΔG° and Q = 1

11-16. Nitrogen dioxide is in equilibrium with its dimer at room temperature:
\[ 2\text{NO}_2 (g) \rightleftharpoons \text{N}_2\text{O}_4 (g) \quad \Delta H < 0 \]

For each of the changes specified in questions 11 to 16, choose the corresponding letter from the following list
(a) [NO₂] increases, [N₂O₄] increases
(b) [NO₂] increases, [N₂O₄] decreases
(c) [NO₂] decreases, [N₂O₄] increases
(d) [NO₂] decreases, [N₂O₄] decreases
(e) [NO₂] unchanged, [N₂O₄] unchanged

11. He (g) is added at constant pressure.
12. He (g) is added at constant volume.
13. The volume of the container is decreased.
14. Some NO₂ is added at constant volume.
15. The temperature is increased at constant volume.
16. A solid catalyst is added at constant temperature and volume.