# CHAPTER 7 QUESTIONS

## Multiple-Choice Questions

Use the following information to answer questions 1-5.

| | |
|---|---|
| Reaction 1: $N_2H_4(l) + H_2(g) \rightarrow 2NH_3(g)$ | $\Delta H = ?$ |
| Reaction 2: $N_2H_4(l) + CH_4O(l) \rightarrow CH_2O(g) + N_2(g) + 3H_2(g)$ | $\Delta H = -37$ kJ/mol$_{rxn}$ |
| Reaction 3: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ | $\Delta H = -46$ kJ/mol$_{rxn}$ |
| Reaction 4: $CH_4O(l) \rightarrow CH_2O(g) + H_2(g)$ | $\Delta H = -65$ kJ./mol$_{rxn}$ |

1. What is the enthalpy change for reaction 1?

   (A) –148 kJ/mol$_{rxn}$
   (B) –56 kJ/mol$_{rxn}$
   (C) –18 kJ/mol$_{rxn}$
   (D) +148 kJ/mol$_{rxn}$

2. If reaction 2 were repeated at a higher temperature, how would the reaction's value for $\Delta G$ be affected?

   (A) It would become more negative because entropy is a driving force behind this reaction.
   (B) It would become more positive because the reactant molecules would collide more often.
   (C) It would become more negative because the gases will be at a higher pressure.
   (D) It will stay the same; temperature does not affect the value for $\Delta G$.

3. Under what conditions would reaction 3 be thermodynamically favored?

   (A) It is always favored.
   (B) It is never favored.
   (C) It is only favored at low temperatures.
   (D) It is only favored at high temperatures.

4. If 64 g of $CH_4O$ were to decompose via reaction 4, approximately how much energy would be released or absorbed?

   (A) 65 kJ of energy will be absorbed.
   (B) 65 kJ of energy will be released.
   (C) 130 kJ of energy will be absorbed.
   (D) 130 kJ of energy will be released.

5. $$2ClF(g) + O_2(g) \leftrightarrow Cl_2O(g) + F_2O(g) \quad \Delta H = 167 \text{ kJ/mol}_{rxn}$$

   During the reaction above, the product yield can be increased by increasing the temperature of the reaction. Why is this effective?

   (A) The reaction is endothermic; therefore adding heat will shift it to the right.
   (B) Increasing the temperature increases the speed of the molecules, meaning there will be more collisions between them.
   (C) The reactants are less massive than the products, and an increase in temperature will cause their kinetic energy to increase more than that of the products.
   (D) The increase in temperature allows for a higher percentage of molecular collisions to occur with the proper orientation to create the product.

6. $$2Al(s) + 3Cl_2(g) \rightarrow 2AlCl_3(s)$$

The reaction above is not thermodynamically favored under standard conditions, but it becomes thermodynamically favored as the temperature decreases toward absolute zero. Which of the following is true at standard conditions?

(A) $\Delta S$ and $\Delta H$ are both negative.
(B) $\Delta S$ and $\Delta H$ are both positive.
(C) $\Delta S$ is negative, and $\Delta H$ is positive.
(D) $\Delta S$ is positive, and $\Delta H$ is negative.

7. 1.50 g of $NaNO_3$ is dissolved into 25.0 mL of water, causing the temperature to increase by 2.2°C. The density of the final solution is found to be 1.02 g/mL. Which of the following expressions will correctly calculate the heat gained by the water as the $NaNO_3$ dissolves? Assume the volume of the solution remains unchanged.

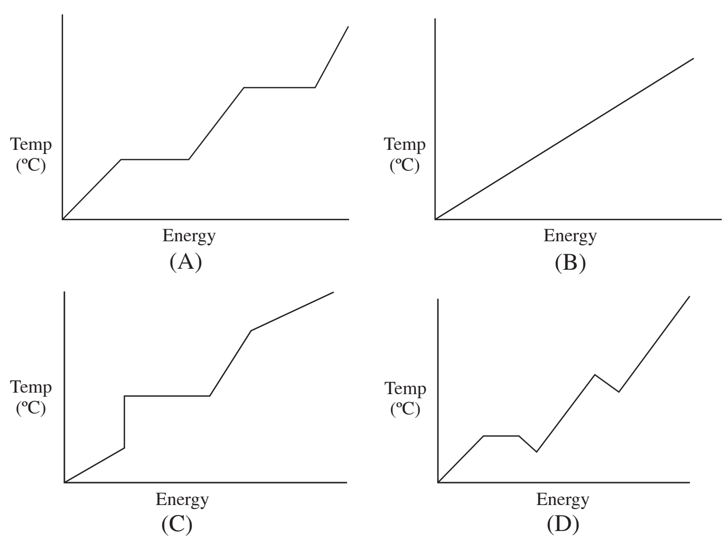
(A) (25.0)(4.18)(2.2)

(B) $\dfrac{(26.5)(4.18)(2.2)}{1.02}$

(C) $\dfrac{(1.02)(4.18)(2.2)}{1.50}$

(D) (25.0)(1.02)(4.18)(2.2)

8. A pure solid substance is heated strongly. It first melts into a liquid, then boils and becomes a gas. Which of the following heating curves correctly shows the relationship between temperature and heat added?



9. $C(s) + 2H_2(g) \rightarrow CH_4(g)$ $\Delta H° = x$

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H° = y$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H° = z$

Based on the information given above, what is $\Delta H°$ for the following reaction?

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

(A) $x + y + z$
(B) $x + y - z$
(C) $z + y - 2x$
(D) $2z + y - x$

10. A student studies two solutions. Solution A has a volume of 100 mL and is at a temperature of 25.0°C. Solution B has a volume of 1000 mL and is at a temperature of 22.0°C. Which of the following statements must be true regarding both solutions?

(A) Solution A has more heat than solution B.
(B) The specific heat capacity of solution A is greater than that of solution B.
(C) If the solutions were to be mixed, heat would transfer from B to A.
(D) Solution B has more thermal energy than solution A.

11. $$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

Based on the information given in the table below, what is $\Delta H°$ for the above reaction?

| Bond | Average bond energy (kJ/mol) |
|---|---|
| H–H | 500 |
| O=O | 500 |
| O–H | 500 |

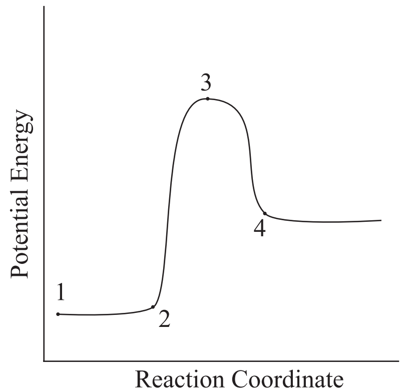
(A) –2,000 kJ
(B) –500 kJ
(C) +1,000 kJ
(D) +2,000 kJ

12. $$H_2O(l) \rightarrow H_2O(s)$$

Which of the following is true for the above reaction?

(A) The value for $\Delta S$ is positive.
(B) The value for $\Delta G$ is zero.
(C) The value for $\Delta H$ is positive.
(D) The reaction is favored at 1.0 atm and 298 K.

Use the following diagram to answer questions 13-15.




13. Which point on the graph shown above corresponds to activated complex or transition state?

(A) 1
(B) 2
(C) 3
(D) 4

14. The distance between which two points is equal to the enthalpy change for this reaction?

(A) Points 1 and 2
(B) Points 1 and 3
(C) Points 1 and 4
(D) Points 2 and 3

15. What would happen to this graph if a catalyst were to be added?

(A) Point 3 would be lower.
(B) The distance between points 2 and 4 would be decreased.
(C) The slope of the line between points 2 and 3 would increase.
(D) Point 4 would be higher.

16.

$$C(s) + O_2(g) \rightarrow CO_2(g) \qquad \Delta H^\circ = -390 \text{ kJ/mol}$$

$$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l) \qquad \Delta H^\circ = -290 \text{ kJ/mol}$$

$$2C(s) + H_2(g) \rightarrow C_2H_2(g) \qquad \Delta H^\circ = +230 \text{ kJ/mol}$$

Based on the information given above, what is $\Delta H^\circ$ for the following reaction?

$$C_2H_2(g) + \frac{5}{2} O_2(g) \rightarrow 2CO_2(g) + H_2O(l)$$

(A) –1,300 kJ
(B) –1,070 kJ
(C) –840 kJ
(D) –780 kJ

17. In which of the following reactions is entropy increasing?

(A) $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
(B) $CO(g) + H_2O(g) \rightarrow H_2(g) + CO_2(g)$
(C) $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$
(D) $2NO_2(g) \rightarrow 2NO(g) + O_2(g)$

18. Consider the following reaction showing photosynthesis:

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(s) + 6O_2(g)$$
$$\Delta H = +\ 2800 \text{ kJ/mol}$$

Which of the following is true regarding the thermal energy in this system?

(A) It is transferred from the surroundings to the reaction.
(B) It is transferred from the reaction to the surroundings.
(C) It is transferred from the reactants to the products.
(D) It is transferred from the products to the reactants.

19.

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

Gaseous hydrogen and fluorine combine in the reaction above to form hydrogen fluoride with an enthalpy change of –540 kJ. What is the value of the heat of formation of HF($g$)?

(A) –1,080 kJ/mol
(B) –270 kJ/mol
(C) 270 kJ/mol
(D) 540 kJ/mol

Use the following information to answer questions 20-23.

When calcium chloride ($CaCl_2$) dissolves in water, the temperature of the water increases dramatically.

20. Which of the following must be true regarding the enthalpy of solution?

(A) The lattice energy in $CaCl_2$ exceeds the bond energy within the water molecules.
(B) The hydration energy between the water molecules and the solute ions exceeds the lattice energy within $CaCl_2$.
(C) The strength of the intermolecular forces between the solute ions and the dipoles on the water molecules must exceed the hydration energy.
(D) The hydration energy must exceed the strength of the intermolecular forces between the water molecules.

21. During this reaction, heat transfers from

(A) the reactants to the products
(B) the reactants to the system
(C) the system to the surroundings
(D) the products to the surroundings

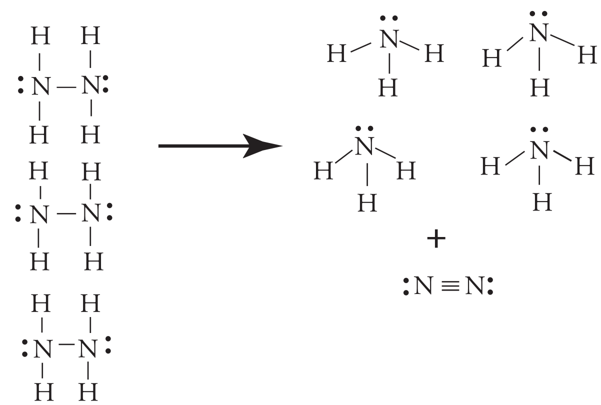
22. Which is the primary driving factor behind this reaction?

(A) Entropy
(B) Enthalpy
(C) Both enthalpy and entropy
(D) Neither enthalpy nor entropy

23. Compared to $CaCl_2$, what must be true regarding the hydration energy of $CaF_2$?

(A) It would be greater because fluoride is smaller than chloride.
(B) It would be the same because the charges of fluoride and chloride are identical.
(C) It would be the same because hydration energy is only dependent on the IMFs present in water.
(D) It would be smaller because the molar mass of $CaF_2$ is smaller than that of $CaCl_2$.

24. The reaction shown in the diagram below is accompanied by a large increase in temperature. If all molecules shown are in their gaseous state, which statement accurately describes the reaction?



(A) It is an exothermic reaction in which entropy increases.
(B) It is an exothermic reaction in which entropy decreases.
(C) It is an endothermic reaction in which entropy increases.
(D) It is an endothermic reaction in which entropy decreases.

## Free-Response Questions

1.

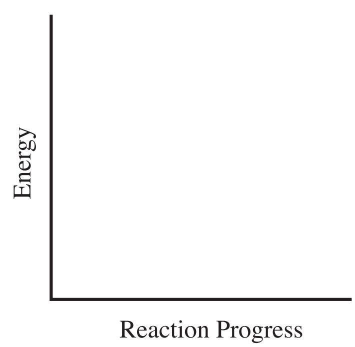
| Substance | Absolute Entropy, $S°$ (J/mol•K) | Molar Mass (g/mol) |
|---|---|---|
| $C_6H_{12}O_6(s)$ | 212.13 | 180 |
| $O_2(g)$ | 205 | 32 |
| $CO_2(g)$ | 213.6 | 44 |
| $H_2O(l)$ | 69.9 | 18 |

Energy is released when glucose is oxidized in the following reaction, which is a metabolism reaction that takes place in the body.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

The standard enthalpy change, $\Delta H°$, for the reaction is –2,801 kJ/mol$_{rxn}$ at 298 K.

(a) Calculate the standard entropy change, $\Delta S°$, for the oxidation of glucose.
(b) Calculate the standard free energy change, $\Delta G°$, for the reaction at 298 K.
(c) Using the axis below, draw an energy profile for the reaction and indicate the magnitude of $\Delta H$.




(d) How much energy is given off by the oxidation of 1.00 gram of glucose?

2.

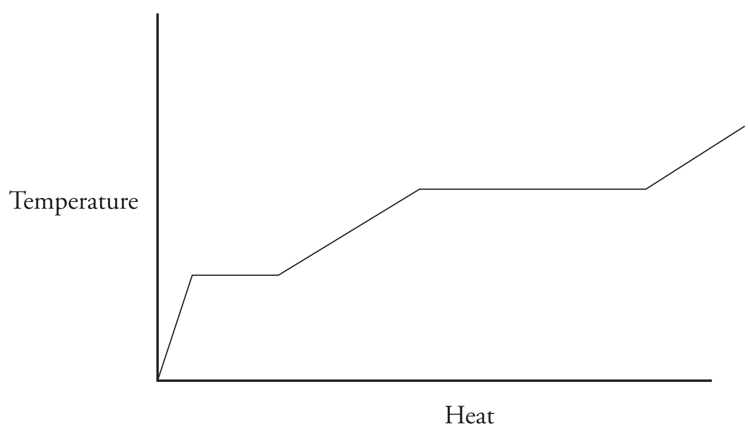
| Bond | Average Bond Dissociation Energy (kJ/mol) |
|---|---|
| C–H | 415 |
| O=O | 495 |
| C=O | 799 |
| O–H | 463 |

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$$

The standard free energy change, $\Delta G°$, for the reaction above is –801 kJ/mol$_{rxn}$ at 298 K.

(a) Use the table of bond dissociation energies to find $\Delta H°$ for the reaction above.
(b) How many grams of methane must react with excess oxygen in order to release 1500 kJ of heat?
(c) What is the value of $\Delta S°$ for the reaction at 298 K?
(d) Give an explanation for the size of the entropy change found in (c).

3.




The diagram above shows how the temperature of a certain covalent substance changes as heat is added to it.

(a) Which is greater for the substance: the heat of fusion or the heat of vaporization? How do you know?
(b) If additional heat is added to the substance, the line would continue at its current slope and never become horizontal again. Why is this?
(c) Reading the graph above, a student theorizes that the specific heat capacity of the substance is greatest in the solid phase. Do you agree? Why or why not?
(d) What would the signs be for the enthalpy and entropy changes as heat continues to be added? Justify your answer.

4. $$CH_3OH\ (l) \rightarrow CH_3OH\ (g)$$

For the boiling of methanol, $CH_3OH$, $\Delta H° = +37.6$ kJ/mol and $\Delta S° = +111$ J/mol • K.

(a) (i) Why is the $\Delta H$ value positive for this process?
(ii) Why is the $\Delta S$ value positive for this process?
(b) What is the boiling point of methanol in degrees Celsius?
(c) How much heat is required to boil 50.0 mL of ethanol if the density of ethanol is 0.789 g/mL?
(d) What will happen to the temperature of the methanol as it boils? Explain.
(e) Would methanol be soluble with water? Why or why not?
(f) Would you expect the boiling point of ethanol, $CH_3CH_2OH$, to be less than, greater than, or the same as methanol? Justify your answer.

5. Ammonia gas reacts with dinitrogen monoxide via the following reaction:

$$2NH_3(g) + 3N_2O(g) \rightarrow 4N_2(g) + 3H_2O(g)$$

The absolute entropy values for the varying substances are listed in the table below.

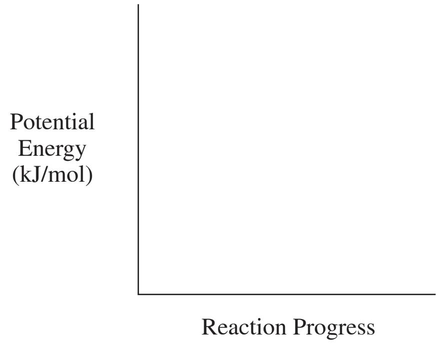
| Substance | $S°$ (J/mol·K) |
|---|---|
| $NH_3(g)$ | 193 |
| $N_2O(g)$ | 220 |
| $N_2(g)$ | 192 |
| $H_2O(g)$ | 189 |

(a) Calculate the entropy value for the overall reaction.

Several bond enthalpies are listed in the table below.

| Bond | Enthalpy (kJ/mol) | Bond | Enthalpy (kJ/mol) |
|---|---|---|---|
| N–H | 388 | N=N | 409 |
| N–O | 210 | N≡N | 941 |
| N=O | 630 | O–H | 463 |

(b) Calculate the enthalpy value for the overall reaction.
(c) Is this reaction thermodynamically favored at 25°C? Justify your answer.
(d) If 25.00 g of $NH_3$ reacts with 25.00 g of $N_2O$:
(i) Will energy be released or absorbed?
(ii) What is the magnitude of the energy change?
(e) On the reaction coordinates below, draw a line showing the progression of this reaction. Label both $\Delta H$ and $E_a$ on the graph.




6. A student designs an experiment to determine the specific heat of aluminum. The student heats a piece of aluminum with a mass of 5.86 g to various temperatures, then drops it into a calorimeter containing 25.0 mL of water. The following data is gathered during one of the trials:

| Initial Temperature of Al (°C) | Initial Temperature of $H_2O$ (°C) | Final Temperature of Al + $H_2O$ (°C) |
|---|---|---|
| 109.1 | 23.2 | 26.8 |

(a) Given that the specific heat of water is 4.18 J/g·°C and assuming its density is exactly 1.00 g/mL, calculate the heat gained by the water.
(b) Calculate the specific heat of aluminum from the experimental data given.
(c) Calculate the enthalpy change for the cooling of aluminum in water in kJ/mol.
(d) If the accepted specific heat of aluminum is 0.900 J/g·°C, calculate the percent error.
(e) Suggest two potential sources of error that would lead the student's experimental value to be different from the actual value. Be specific in your reasoning and make sure any identified error can be quantitatively tied to the student's results.