Unit 12 FRQ Practice Name

2024

$$H_2C_4H_2O_4(aq) + 2\ NaHCO_3(aq) \rightarrow 2\ CO_2(g) + 2\ H_2O(l) + Na_2C_4H_2O_4(aq)$$

a. The reaction above has a value of ΔS° greater than zero. Using particle-level reasoning, explain why the entropy increases as the reaction progresses.

The student notices that the temperature of the reaction mixture decreases as the reaction takes place and correctly determines that the reaction is endothermic.

b. The student claims that the reaction is thermodynamically favorable at all temperatures because $\Delta S^\circ_{rxn} > 0$ and the reaction is endothermic. Do you agree or disagree with the student's claim? Justify your answer.

2022

$$CH_3OH(g) \leftrightarrow CO(g) + 2\ H_2(g) \qquad \Delta H^\circ = 90.0\ kJ/mol_{rxn}$$

The values of the standard molar entropies of the compound involved in the reaction are given in the following table.

Substance	S° (J/(K·mol))
$CH_3OH(g)$	240.
$CO(g)$	198
$H_2(g)$	131

a. Use the data in the table to calculate the value of the standard entropy change, ΔS°, in $J/(K\bullet mol_{rxn})$, for the reaction.

b. Calculate the value of ΔG°, in kJ/mol_{rxn}, for the reaction at 375 K. Assume that ΔH° and ΔS° are independent of temperature.

2021

At high temperature, SiH_4 decomposes to form solid silicon and hydrogen gas.

a. Write the balanced equation for the reaction.

A table of absolute entropies of some substances is given below.

Substance	$S°$ (J/(mol · K))
$H_2(g)$	131
$Si(s)$	18
$SiH_4(g)$	205

b. Explain why the absolute molar entropy of Si(s) is less than that of H_2(g).

c. Calculate the value, in J/(mol•K), of ΔS° for the reaction.

d. The reaction is thermodynamically favorable at all temperatures. Explain why the reaction occurs only at high temperatures.

2019

$$H_2NCONH_2\,(s) \rightarrow H_2NCONH_2\,(aq) \qquad \Delta H_{soln} > 0$$

	$S°$ (J/(mol·K))
$H_2NCONH_2(s)$	104.6
$H_2NCONH_2(aq)$	?

a. The entropy change for the dissolution of solid urea, H_2NCONH_2 (s), is 70.1 J/(mol•K) at 25˚C. Using the information in the table above, calculate the absolute molar entropy, S˚, for aqueous urea, H_2NCONH_2 (aq).

b. Using particle-level reasoning, explain why ΔS°_{soln} is positive for the dissolution of urea in water.

c. The student claims that ΔS˚ for the process contributes to the thermodynamic favorability of the dissolution of urea at 25˚C. Use the thermodynamic information above to support the student's claim.

2006

$$CO_{(g)} + \frac{1}{2} O_{2(g)} \rightarrow CO_{2(g)}$$

The combustion of carbon monoxide is represented by the equation above.
a) Determine the value of the standard enthalpy change, ΔH_{rxn}, for the combustion of $CO_{(g)}$ at 298 K using the following information.

$$C_{(s)} + \frac{1}{2} O_{2(g)} \rightarrow CO_{(g)} \qquad \Delta H^o_{298} = -110.5 \text{ kJ mol}^{-1}$$

$$C_{(s)} + O_{2(g)} \rightarrow CO_{2(g)} \qquad \Delta H^o_{298} = -393.5 \text{ kJ mol}^{-1}$$

b) Determine the value of the standard entropy change, ΔS^o_{rxn}, for the combustion of $CO_{(g)}$ at 298 K using the information in the following table.

Substance	S^o_{298} (J mol^{-1} K^{-1})
$CO_{(g)}$	197.7
$CO_{2(g)}$	213.7
$O_{2(g)}$	205.1

c) Determine the standard free energy change, ΔG^o_{rxn}, for the reaction at 298 K. Include units with your answer.

d) Is the reaction spontaneous under standard conditions at 298 K. Justify your answer.

e) Calculate the value of the equilibrium constant, K_{eq}, for the reaction at 298 K.

2001B

$$2\ NO(g) + O_2(g) \rightarrow 2\ NO_2(g) \qquad \Delta H° = -114.1\ kJ, \qquad \Delta S° = -146.5\ J\ K^{-1}$$

The reaction represented above is one that contributes significantly to the formation of photochemical smog.

(a) Calculate the quantity of heat released when 73.1 g of $NO(g)$ is converted to $NO_2(g)$. $\Delta H°$ is for the entire reaction, not per mole.

(b) For the reaction at 25ºC, the value of the standard free-energy change, ΔGº, is -70.4 kJ.

(i) Calculate the value of the equilibrium constant, K_{eq}, for the reaction at 25ºC.

(ii) Indicate whether the value of ΔGº would become more negative, less negative, or remain unchanged as the temperature is increased. Justify your answer.

(c) Use the data in the table below to calculate the value of the standard molar entropy, Sº, for $O_2(g)$ at 25ºC.

	Standard Molar Entropy, Sº (J K^{-1} mol^{-1})
$NO(g)$	210.8
$NO_2(g)$	240.1

(d) Use the data in the table below to calculate the bond energy, in kJ mol^{-1}, of the nitrogen-oxygen bond in NO_2 . Assume that the bonds in the NO_2 molecule are equivalent (*i.e.*, they have the same energy).

	Bond Energy (kJ mol^{-1})
Nitrogen-oxygen bond in NO	607
Oxygen-oxygen bond in O_2	495
Nitrogen-oxygen bond in NO_2	?

1983B

$$CO(g) + 2\ H_2(g) \rightarrow CH_3OH(l) \quad \Delta H^\circ = -128.1\ \text{kJ}$$

	ΔH_f° (kJ mol^{-1})	ΔG_f° (kJ mol^{-1})	S° (J mol^{-1} K^{-1})
$CO(g)$	-110.5	-137.3	+197.9
$CH_3OH(l)$	-238.6	-166.2	+126.8

The data in the table above were determined at 25°C.

(a) Calculate ΔG° for the reaction above at 25°C.

(b) Calculate K_{eq} for the reaction above at 25°C.

(c) Calculate ΔS° for the reaction above at 25°C.

(d) In the table above, there is no data for H_2. What are the values of ΔH_f°, ΔG_f°, and of the absolute entropy, S°, for H_2 at 25°C?

1985D

(a) When liquid water is introduced into an evacuated vessel at 25C, some of the water vaporizes. Predict how the enthalpy, entropy, free energy, and temperature change in the system during this process. Explain the basis for each of your predictions.

(b) When a large amount of ammonium chloride is added to water at 25C, some of it dissolves and the temperature of the water decreases. Predict how the enthalpy, entropy, and free energy change in the system during this process. Explain the basis for each of your predictions.

(c) If the temperature of the aqueous ammonium chloride system in part (b) were to be increased to 30C, predict how the solubility of the ammonium chloride would be affected. Explain the basis for each of your predictions.