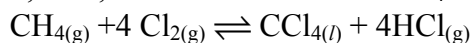


AP Chemistry Thermodynamics Review Worksheet

1. Methane, CH_4 and chlorine, Cl_2 , are reacted to form carbon tetrachloride, CCl_4 and hydrogen chloride, HCl at 25°C . The heat of reaction, ΔH° , is $-429.8 \text{ kJ mol}^{-1}$ of CH_4 reacted. The equation is:

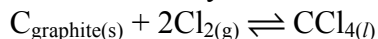


Substance	Heat of formation, ΔH_f° , kJ mol^{-1}	Absolute entropy, S° , $\text{J mol}^{-1}\text{K}^{-1}$
$\text{C}_{\text{graphite}}(\text{s})$	0	5.740
$\text{CH}_4(\text{g})$	-74.86	186.2
$\text{CCl}_4(\text{l})$?	216.4
$\text{Cl}_2(\text{g})$	0	223.0
$\text{HCl}(\text{g})$	-92.31	186.8

- a) What is the standard heat of formation, ΔH_f° , for carbon tetrachloride at 25°C ?

- b) Calculate the standard entropy change, ΔS° , for the reaction at 25°C .

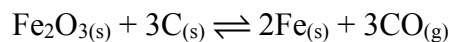
- c) Theoretically, carbon tetrachloride can be formed by the reaction:



Calculate the standard free energy of formation, ΔG_f° , for carbon tetrachloride at 25°C .

- d) Calculate the value of the equilibrium constant, K , for the reaction in part (c).

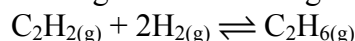
2. For the reaction:



ΔH° , ΔS° , and ΔG° are all positive when the substances are in their standard states at 25°C .

- a) What is the physical significance of the signs of ΔH° , ΔS° , and ΔG° for this reaction?
- b) Which of the substances would exist in the highest amounts in an equilibrium mixture at 25°C ? Explain how you determined your answer.
- c) This reaction is used as a step in the recovery of iron from its ore. Use thermodynamic concepts to explain how the yield of iron can be maximized.

3. Ethane can be made from ethyne according to the following reaction:



Substance	S° ($\text{J mol}^{-1} \text{K}^{-1}$)	ΔH_f° (kJ mol^{-1})
$\text{C}_2\text{H}_2(\text{g})$	200.9	226.7
$\text{H}_2(\text{g})$	130.7	0
$\text{C}_2\text{H}_6(\text{g})$	—	-84.7

Bond	Bond energy kJ mol^{-1}
C–C	347
C=C	611
C–H	414
H–H	436

- a) If the value of the standard entropy change, ΔS° , for the reaction is -232.7 joules per mole·Kelvin, calculate the standard molar entropy, S° of C_2H_6 gas.
- b) Calculate the value of the standard free-energy change, ΔG° , for the reaction at 25°C . What does the sign of the ΔG° indicate about the reaction?
- c) Calculate the value of the equilibrium constant, K , for the reaction at 298 K .
- d) Calculate the bond energy of the carbon–carbon triple bond in C_2H_2 in kilojoules per mole.

4. For the gaseous equilibrium represented below, it is observed that greater amounts of PCl_3 and Cl_2 are produced when the temperature is increased.



- a) What is the sign of ΔS° for the reaction? Explain.
- b) What change, if any, will occur in ΔG° for the reaction as the temperature is increased? Explain your answer in terms of thermodynamic principles.
- c) If He gas is added to the original reaction mixture at constant volume and temperature, what will happen to the partial pressure of Cl_2 ? Explain.
- d) If the volume of the reaction mixture is decreased at constant temperature to half the original volume, what will happen to the number of moles of Cl_2 in the reaction vessel? Explain.

Answers: 1a) -135.42 kJ/mol ; 1b) $-114.6 \text{ J/mol}\cdot\text{K}$; 1c) -65.3 kJ/mol ; 1d) 2.83×10^{11} ; 3a) $229.6 \text{ J/mol}\cdot\text{K}$; 3b) -242 kJ/mol ; 3c) 2.76×10^{42} ; 3d) 820 kJ/mol .