Energy and Chemical Change

1. Calculate the amount of heat released in the complete combustion of 8.17 g of Al to form $Al_2O_3(s)$ at 25°C and 1 atm. ΔH_f° for $Al_2O_3(s) = -1680$ kJ/mol.

$4Al(s) + 3O_2(g) \longrightarrow 2Al_2O_3(s)$

2. From the following data at 25°C,

$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g) \quad \Delta H = -185$ kJ

$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g) \quad \Delta H = -483.7$ kJ

calculate ΔH at 25°C for the reaction below.

$4HCl(g) + O_2(g) \longrightarrow 2Cl_2(g) + 2H_2O(g)$

3. Determine ΔS for the reaction

$SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(l)$,

given the following entropies.

Compound	Entropy (J/mol·K)
$SO_3(g)$	256.8
$H_2O(l)$	70.0
$H_2SO_4(l)$	156.9

4. Calculate the molar entropy of vaporization for liquid hydrogen iodide at its boiling point, −34.55°C.

$HI(l) \rightleftarrows HI(g) \qquad \Delta H_{vap} = 19.76$ kJ/mol

5. Ozone (O_3) in the atmosphere may react with nitric oxide (NO).

$O_3(g) + NO(g) \longrightarrow NO_2(g) + O_2(g)$

From the following data, calculate the ΔG° in kJ for the reaction at 25°C and determine whether the reaction is spontaneous.

$\Delta H^\circ = -199$ kJ

$\Delta S^\circ = -4.1$ J/K

6. For the reaction $H_2(g) + S(s) \longrightarrow H_2S(g)$, $\Delta H = -20.2$ kJ and $\Delta S = 43.1$ J/K. When will the reaction be spontaneous?

7. The following reaction is nonspontaneous at 25°C.

$Cu_2O(s) \longrightarrow 2Cu(s) + \frac{1}{2}O_2(g)$

$\Delta H_f^\circ = 168.6$ kJ

If $\Delta S = 75.8$ J/K, what is the lowest temperature at which the reaction will be spontaneous?

8. Calculate ΔH° at 25°C for the reaction below.

$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$

$-206.0 \qquad 0 \qquad -350.5 \qquad -296.8$

ΔH_f°(kJ/mol)

9. How much heat is evolved in the formation of 35.0 g of $Fe_2O_3(s)$ at 25°C and 1.00 atm pressure by the following reaction?

$4Fe(s) + 3O_2(g) \longrightarrow 2Fe_2O_3(s)$

ΔH_f° (kJ/mol)	0	0	−824.2

10. Calculate the standard heat of vaporization, ΔH_{vap}, for tin(IV) chloride, $SnCl_4$.

$\Delta H_f^\circ = -511.3$ kJ/mol for $SnCl_4(l)$ and −471.5 kJ/mol for $SnCl_4(g)$.

11. Given the following data at 298 K, calculate ΔS for the given reaction.

$2Ag_2O(s) \longrightarrow 4Ag(s) + O_2(g)$

ΔS (J/mol·K)	121.3	42.6	205.2

12. Calculate the $\Delta G°$ at 298 K for the following reaction.

$Fe_2O_3(s) + 13CO(g) \longrightarrow 2Fe(CO)_5(g) + 3CO_2(g)$

−824.2	−110.5	−733.8	−393.5
	$\Delta H°$ (kJ/mol)		
87.4	197.6	445.2	213.6
	$\Delta S°$ (J/mol·K)		

13. Estimate the temperature at which $\Delta G = 0$ for the following reaction.

$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$

$\Delta H = -176$ kJ, $\Delta S = -284.5$ J/K

14. Consider the reaction below at 25°C for which $\Delta S = 16.1$ J/K.

$CH_4(g) + N_2(g) + 163.8\text{ kJ} \longrightarrow HCN(g) + NH_3(g)$

At what temperature will this reaction be spontaneous?

15. Estimate the temperature above which the following reaction is not spontaneous.

$PbS(s) + 2HCl(g) \longrightarrow PbCl_2(s) + H_2S(g)$

−100.4	−92.31	−359.4	−20.60
	$\Delta H_f°$ (kJ/mol)		
−98.70	−95.30	−314.1	−33.60
	$\Delta G°$ (kJ/mol)		

16. Copper metal has a specific heat of 0.385 J/g·°C and a melting point of 1083°C. Calculate the amount of heat required to raise the temperature of 22.8 g of copper from 20.0°C to 875°C.

17. How many degrees of temperature rise will occur when a 25.0-g block of aluminum absorbs 10.0 kJ of heat? The specific heat of aluminum is 0.897 J/g·°C.

18. Find the standard enthalpy of formation for ethylene, $C_2H_4(g)$, given the following data.

$C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l)$

$\Delta H° = -1411$ kJ

$C(s) + O_2(g) \longrightarrow CO_2(g)$

$\Delta H° = -393.5$ kJ

$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$

$\Delta H° = -285.8$ kJ

19. Glycine is important for biological energy. The combustion of glycine is given by the following equation.

$4C_2H_5O_2N(s) + 9O_2(g) \longrightarrow 8CO_2(g) + 10H_2O(l) + 2N_2(g)$

$\Delta H = -3857$ kJ

Given that $\Delta H_f°\ CO_2(g) = -393.5$ kJ/mol and $\Delta H_f°\ H_2O(l) = -285.8$ kJ/mol, calculate the enthalpy of formation per mole of glycine.

20. At body temperature, 2404 J is required to evaporate 1 g of water. After vigorous exercise, a person feels chilly because the body is giving up heat to evaporate the perspiration. A typical person perspires 25 mL of water after 20 minutes of exercise. How much body heat is used to evaporate this water?