Enthalpy and The First Law DCI

Name	Section

1 Energy in the form of heat can be either released (exothermic) or absorbed (endothermic) in a chemical reaction. The heat, called enthalpy, is a driving force for chemical reactions. Predict which of the following thermodynamically favored reactions are exothermic and which are endothermic.

a) $H_2O_{(l)} \rightarrow H_2O_{(g)}$ at 25 °C   **endothermic**

b) $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$ **exothermic**

c) $Ba(OH)_2 \cdot 8H_2O_{(s)} + 2NH_4Cl_{(s)} \rightarrow BaCl_{2(aq)} + 2NH_{3(g)} + 10H_2O_{(l)}$ **endothermic**

d) $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$ or $_{(g)}$ **exothermic**

e) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$ **exothermic**

f) $Al_{(s)} + \frac{3}{2}Br_{2(l)} \rightarrow AlBr_{3(s)}$ **exothermic**

2. A formation reaction is a chemical reaction depicting the formation of one mole of a substance from its naturally occurring elemental sources. Which of the reactions in question 1 are formation reactions?

A formation reaction is characterized as having elements in their standard states forming 1 mol of product.
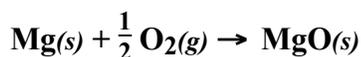
So d and f are both formation reactions.

d) $H_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow H_2O_{(l)}$ or $_{(g)}$ **and f)** $Al_{(s)} + \frac{3}{2}Br_{2(l)} \rightarrow AlBr_{3(s)}$
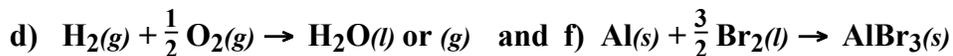
However, b is NOT a formation reaction

b) $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

The reactants are in their standard state, however 2 moles of product are formed. For this reaction to be a formation reaction the equation would have to be;

$Mg_{(s)} + \frac{1}{2}O_{2(g)} \rightarrow MgO_{(s)}$

3. A table of enthalpies of formation, ΔH_f°, for selected substance is at the end of this DCI. Write the mathematical equation which relates the standard heat of reaction to the heats of formation of the reactants and products of the chemical reaction.

The heat (enthalpy) of reaction can be determined by adding together the enthalpies of formation associated with a series of formation reactions which can generate the desired reaction.

$$\Delta H_{rxn}^\circ = \Sigma\Delta H_f^\circ \text{ (products)} - \Sigma\Delta H_f^\circ \text{ (reactants)}$$

4. Calculate $\Delta H^\circ_{reaction}$ for the following chemical reactions.

a) $H_2O_{(l)} \rightarrow H_2O_{(g)}$ at 25 ˚C (note: this reaction is NOT thermodynamically favored at 25 ˚C)

$\Delta H_{rxn}^\circ = +44$ kJ mol^{-1}

b) $2Mg_{(s)} + O_{2(g)} \rightarrow 2MgO_{(s)}$

$\Delta H_{rxn}^\circ = -1202$ kJ mol^{-1}

c) $Ba(OH)_2 \cdot 8H_2O_{(s)} + 2NH_4Cl_{(s)} \rightarrow BaCl_{2(aq)} + 2NH_{3(g)} + 10H_2O_{(l)}$

$\Delta H_{rxn}^\circ = \Sigma\Delta H_f^\circ \text{ (products)} - \Sigma\Delta H_f^\circ \text{ (reactants)}$

$= \Delta H_f^\circ \text{ (BaCl}_2) + 2\Delta H_f^\circ \text{ (NH}_3) + 10\Delta H_f^\circ \text{ (H}_2O)$

$- (\Delta H_f^\circ \text{ (Ba(OH)}_2 \cdot 8H_2O) + 2\Delta H_f^\circ \text{ (NH}_4Cl))$

$= (-872 \text{ kJ mol}^{-1}) + 2(-46 \text{ kJ mol}^{-1}) + 10(-286 \text{ kJ mol}^{-1}) - ((-3342 \text{ kJ mol}^{-1}) + 2(-314 \text{ kJ mol}^{-1}))$

$= (-872 \text{ kJ mol}^{-1} + (-92 \text{ kJ mol}^{-1}) + (-2860 \text{ kJ mol}^{-1})) - (-3342 \text{ kJ mol}^{-1} + (-628 \text{ kJ mol}^{-1}))$

$= 146$ kJ mol^{-1}

d) $H_{2(g)} + \frac{1}{2} O_{2(g)} \rightarrow H_2O_{(l)}$ or $_{(g)}$

$\Delta H_{rxn}^\circ = -286$ kJ mol^{-1} **for the liquid phase and** -242 kJ mol^{-1} **for the gas phase**

e) $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

$\Delta H_{rxn}^\circ = \Sigma\Delta H_f^\circ \text{ (products)} - \Sigma\Delta H_f^\circ \text{ (reactants)}$

$= (\Delta H_f^\circ \text{ (CO}_2) + 2\Delta H_f^\circ \text{ (H}_2O)) - (\Delta H_f^\circ \text{ (CH}_4) + 2\Delta H_f^\circ \text{ (O}_2))$

$= [(-393.5 \text{ kJ mol}^{-1}) + (-285.8 \text{ kJ mol}^{-1})] - [(-74.8 \text{ kJ mol}^{-1}) + (0)]$

$= -890$ kJ mol^{-1}

f) $Al_{(s)} + \frac{3}{2} Br_{2(l)} \rightarrow AlBr_{3(s)}$
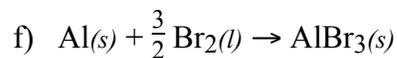
$$\Delta H^\circ_{rxn} = \Sigma \Delta H^\circ_f \text{ (products)} - \Sigma \Delta H^\circ_f \text{ (reactants)}$$

$$= \Delta H^\circ_f \text{ (AlBr}_3\text{)} - [\Delta H^\circ_f \text{ (Al)} + \frac{3}{2} \Delta H^\circ_f \text{ (Br}_2\text{)}]$$

$$= (-526.3 \text{ kJ mol}^{-1}) - [(0) + \frac{3}{2} (0)] = -526.3 \text{ kJ mol}^{-1}$$

4. The natural tendency for spontaneous chemical reactions is to release heat. Is enthalpy an absolute predictor of thermodynamically favorability?

   No, enthalpy is not an absolute predictor of whether a reaction is thermodynamically favored.

Substance and State	ΔH°_f (kJ/mol)	Substance and State	ΔH°_f (kJ/mol)
C(s) (graphite)	0	HCl(g)	-92.3
C(s) (diamond)	2	HBr(g)	-36.4
CO(g)	-110.5	HI(g)	26.5
CO$_2$(g)	–393.5	I$_2$(g)	62.25
CH$_4$(g)	–75	O$_2$(g)	0
CH$_3$OH(g)	-201	O(g)	249
CH$_3$OH(l)	-239	O$_3$(g)	143
H$_2$CO(g)	-116		
CCl$_4$(l)	-135.4	N$_2$(g)	0
HCOOH(g)	-363	NH$_3$(g)	-46
HCN(g)	135.1	NH$_3$(aq)	-80
CS$_2$(g)	117.4	NH$_4^+$(aq)	-132
CS$_2$(l)	89.7	NH$_4$Cl(s)	-314.4
C$_2$H$_2$(g)	227	N$_2$H$_4$(l)	50.6
C$_2$H$_4$(g)	52	NO(g)	90.25
CH$_3$CHO(g)	-166	NO$_2$(g)	33.18
C$_2$H$_5$OH(l)	-278	N$_2$O(g)	82.0
C$_2$H$_5$O$_2$N(g)	-533	N$_2$O$_4$(g)	9.16
C$_2$H$_6$(g)	-84.7	N$_2$O$_4$(l)	20
C$_3$H$_6$(g)	20.9	HNO$_3$(aq)	-207.36
C$_3$H$_8$(g)	-104	HNO$_3$(l)	-174.10
C$_4$H$_{10}$(g)	-126	NH$_4$ClO$_4$(s)	-295
C$_8$H$_{18}$(l)	-208		
CH$_2$ = CHCN(l)	152		
CH$_3$COOH(l)	-484	S$_2$Cl$_2$(g)	-18
C$_6$H$_{12}$O$_6$(s)	-1275	SO$_2$(g)	-296.83
		H$_2$S(g)	-20.6
Cl$_2$(g)	0	SOCl$_2$(g)	-213
Cl$_2$(aq)	-23		
Cl$^-$(aq)	-167.5	SiCl$_4$(g)	-657
		SiO$_2$(s)	-910.94
		SiF$_4$(g)	-1614.9
H$_2$(g)	0		
H(g)	217	Ba(OH)$_2$·8H$_2$O(s)	-3342
H$^+$(aq)	0	BaCl$_2$(aq)	-872
OH$^-$(aq)	-230	AlBr$_3$(s)	-526
H$_2$O(l)	-286		
H$_2$O(g)	-242	ZnS(s)	-206