Non Sibi High School

Andover's Chem 300: Accelerated/Honors Chemistry

Chapter 13, Review Quiz 1 Answers

1

If 125 kilograms of methanol, CH_3OH, is burned according to the combustion equation below, how much heat will be released?

$$2CH_3OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 4H_2O(l) \;\; \Delta H = -1453\,\mathrm{kJ/mol}$$

$$125\,\mathrm{kg}\left(\frac{1000\,\mathrm{g}}{1\,\mathrm{kg}}\right)\left(\frac{1\,\mathrm{mol\,CH_3OH}}{32.04\,\mathrm{g}}\right)\left(\frac{-1453\,\mathrm{kJ}}{2\,\mathrm{mol\,CH_3OH}}\right) = -2.83\times10^{6}\,\mathrm{kJ}$$

2

If 3.55 kJ of heat are absorbed during the decomposition reaction below, how many milliliters of sulfur trioxide gas, measured at 22°C and 712 mmHg, will decompose?

$$2SO_3(g) \longrightarrow 2SO_2(g) + O_2(g) \;\; \Delta H = 198\,\mathrm{kJ/mol}$$

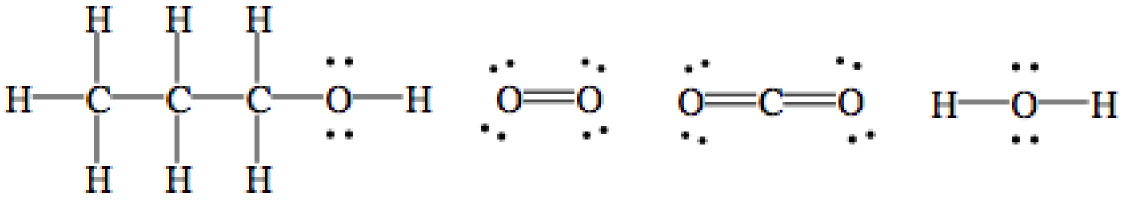
$$3.55\,\mathrm{kJ}\left(\frac{2\,\mathrm{mol\,SO_3}}{198\,\mathrm{kJ}}\right) = 0.03586\,\mathrm{mol\,SO_3}$$

$$\frac{0.03586\,\mathrm{mol}\times 0.0821\,\frac{\mathrm{L\cdot atm}}{\mathrm{mol\cdot K}}\times(22+273)\,\mathrm{K}}{\frac{712}{760}\,\mathrm{atm}} = 0.927\,\mathrm{L}\left(\frac{1000\,\mathrm{mL}}{1\,\mathrm{L}}\right) = 927\,\mathrm{mL\,SO_3}$$

3

For the reaction $2C_3H_7OH(g) + 9O_2(g) \longrightarrow 6CO_2(g) + 8H_2O(g)$, estimate ΔH using average bond energies.

Lewis structures:



$$\begin{gathered}\Delta\mathrm{H}\text{ (estimated)} = \\ (2\times 7)(\mathrm{C-H}) + (2\times 2)(\mathrm{C-C}) + (2\times 1)(\mathrm{C-O}) + (2\times 1)(\mathrm{O-H}) + (9\times 1)(\mathrm{O=O}) \\ -(6\times 2)(\mathrm{C=O}) - (8\times 2)(\mathrm{O-H}) \\ = 14(414) + 4(347) + 2(360) + 2(464) + 9(498) - 12(745) - 16(464) \\ = -3050\text{ kJ/mol}\end{gathered}$$

4

Calculate $\Delta\mathrm{H}$ for the reaction $\mathrm{C(s)} + 2\mathrm{H_2(g)} + \frac{1}{2}\mathrm{O_2(g)} \longrightarrow \mathrm{CH_3OH(g)}$ using the following three reactions:

I) $\mathrm{CO_2(g)} \longrightarrow \mathrm{C(s)} + \mathrm{O_2(g)}\ \ \Delta\mathrm{H_I} = 394\,\mathrm{kJ/mol}$

II) $\mathrm{H_2(g)} + \frac{1}{2}\mathrm{O_2(g)} \longrightarrow \mathrm{H_2O(g)}\ \ \Delta\mathrm{H_{II}} = -242\,\mathrm{kJ/mol}$

III) $2\mathrm{CH_3OH(g)} + 3\mathrm{O_2(g)} \longrightarrow 2\mathrm{CO_2(g)} + 4\mathrm{H_2O(g)}\ \ \Delta\mathrm{H_{III}} = -1354\,\mathrm{kJ/mol}$

$$\begin{gathered}\mathrm{C(s)} + \mathrm{O_2(g)} \longrightarrow \mathrm{CO_2(g)}\ \ \Delta\mathrm{H} = -1(394\,\mathrm{kJ/mol}) = -394\,\mathrm{kJ/mol} \\ 2\mathrm{H_2(g)} + \mathrm{O_2(g)} \longrightarrow 2\mathrm{H_2O(g)}\ \ \Delta\mathrm{H} = 2(-242\,\mathrm{kJ/mol}) = -484\,\mathrm{kJ/mol} \\ \underline{\mathrm{CO_2(g)} + 2\mathrm{H_2O(g)} \longrightarrow \mathrm{CH_3OH(g)} + \frac{3}{2}\mathrm{O_2(g)}\ \ \Delta\mathrm{H} = -\frac{1}{2}(-1354\,\mathrm{kJ/mol}) = 677\,\mathrm{kJ/mol}} \\ \mathrm{C(s)} + 2\mathrm{H_2(g)} + \frac{1}{2}\mathrm{O_2(g)} \longrightarrow \mathrm{CH_3OH(g)}\ \ \Delta\mathrm{H} = -201\,\mathrm{kJ/mol}\end{gathered}$$

5

Write the balanced formation reaction, including physical states, for solid sodium iodate, $\mathrm{NaIO_3}$.

$$\mathrm{Na(s)} + \frac{1}{2}\mathrm{I_2(s)} + \frac{3}{2}\mathrm{O_2(g)} \longrightarrow \mathrm{NaIO_3(s)}$$

Compound	ΔH_f° (kJ/mol)
NO(g)	90.
NO_2(g)	33

6

Calculate ΔH° for the reaction $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ using the following information:

$$\Delta H^\circ = 2(33) - 2(90) - 1(0) = -114\,\mathrm{kJ/mol}$$

7

The specific heat of magnesium metal is 1.05 J/g·°C. How much heat in kilojoules is lost when a 225 gram sample of magnesium metal is cooled from 625°C to 125°C?

$$q = 225\,\mathrm{g}\left(\frac{1.05\,\mathrm{J}}{\mathrm{g}\cdot^\circ\mathrm{C}}\right)(125-625)^\circ\mathrm{C}\left(\frac{1\,\mathrm{kJ}}{1000\,\mathrm{J}}\right) = -118\,\mathrm{kJ}$$

8

In an insulated calorimeter, a 475 gram piece of tin metal originally at 132°C was added to 135 grams of water originally at 19°C. The final temperature of the tin-water mixture was 36°C. Determine the specific heat of tin.

$$q_{\mathrm{Sn\,lost}} = -q_{\mathrm{water\,gained}}$$
$$475\,\mathrm{g}(s_{\mathrm{Sn}})(36-132)^\circ\mathrm{C} = -135\,\mathrm{g}\left(\frac{4.18\,\mathrm{J}}{\mathrm{g}\cdot^\circ\mathrm{C}}\right)(36-19)^\circ\mathrm{C}$$
$$s_{\mathrm{Sn}} = 0.21\,\mathrm{J/g}\cdot^\circ\mathrm{C}$$

9

The specific heat of tungsten metal is 0.13 J/g·°C. In an insulated calorimeter, a 955 gram piece of tungsten metal originally at 375°C was added to 725 grams of water originally at 18°C. Determine the final temperature of the tungsten-water mixture.

$$q_{\mathrm{W\,lost}} = -q_{\mathrm{water\,gained}}$$
$$955\,\mathrm{g}\left(\frac{0.13\,\mathrm{J}}{\mathrm{g}\cdot^\circ\mathrm{C}}\right)(t_{\mathrm{final}} - 375^\circ\mathrm{C}) = -725\,\mathrm{g}\left(\frac{4.18\,\mathrm{J}}{\mathrm{g}\cdot^\circ\mathrm{C}}\right)(t_{\mathrm{final}} - 18^\circ\mathrm{C})$$
$$t_{\mathrm{final}} = 32^\circ\mathrm{C}$$

10

In an insulated calorimeter, 18.2 grams of solid cesium hydroxide at 22.3°C was dissolved in 135.7 grams of water also at 22.3°C, after which the final temperature of the mixed solution was 36.9°C. If the specific heat of the mixed solution was 3.87 J/g·°C, determine ΔH for the dissolving process CsOH(s) $\longrightarrow$ CsOH(aq) in kJ/mol CsOH.

$$\mathrm{q_{rxn\,lost}} = -\mathrm{q_{soln\,gained}} = -(18.2+135.7)\mathrm{g}\left(\frac{3.87\,\mathrm{J}}{\mathrm{g}\cdot^{\circ}\mathrm{C}}\right)(36.9-22.3)^{\circ}\mathrm{C}\left(\frac{1\,\mathrm{kJ}}{1000\,\mathrm{J}}\right) = -8.696\,\mathrm{kJ}$$

$$\mathrm{n_{CsOH}} = 18.2\,\mathrm{g}\left(\frac{1\,\mathrm{mol}}{149.9\,\mathrm{g}}\right) = 0.1214\,\mathrm{mol\,CsOH}$$

$$\Delta\mathrm{H} = \frac{-8.696\,\mathrm{kJ}}{0.1214\,\mathrm{mol\,CsOH}} = -71.6\,\mathrm{kJ/mol\,CsOH}$$

11

In an insulated calorimeter, 55.7 mL of 1.91 M acetic acid was mixed with 62.6 mL of 1.83 M sodium hydroxide, with both solutions originally at 18.2°C. The final temperature of the mixed solutions was 30.1°C. The density of the mixed solutions was 1.03 g/mL and the specific heat of the mixed solutions was 3.96 J/g·°C. Write a balanced molecular equation, including physical states, and determine ΔH for the neutralization reaction in kJ/mol of water formed.

$$\mathrm{HCH_3COO(aq) + NaOH(aq) \longrightarrow H_2O(l) + NaCH_3COO(aq)}$$

$$\mathrm{q_{rxn\,lost}} = -\mathrm{q_{soln\,gained}} = -(55.7+62.6)\mathrm{mL}\left(\frac{1.03\,\mathrm{g}}{1\,\mathrm{mL}}\right)\left(\frac{3.96\,\mathrm{J}}{\mathrm{g}\cdot^{\circ}\mathrm{C}}\right)(30.1-18.2)^{\circ}\mathrm{C}\left(\frac{1\,\mathrm{kJ}}{1000\,\mathrm{J}}\right) = -5.742\,\mathrm{kJ}$$

$$55.7\,\mathrm{mL}\left(\frac{1\,\mathrm{L}}{1000\,\mathrm{mL}}\right)\left(\frac{1.91\,\mathrm{mol\,HCH_3COO}}{1\,\mathrm{L}}\right)\left(\frac{1\,\mathrm{mol\,H_2O}}{1\,\mathrm{mol\,HCH_3COO}}\right) = 0.1064\,\mathrm{mol\,H_2O}$$

$$62.6\,\mathrm{mL}\left(\frac{1\,\mathrm{L}}{1000\,\mathrm{mL}}\right)\left(\frac{1.83\,\mathrm{mol\,NaOH}}{1\,\mathrm{L}}\right)\left(\frac{1\,\mathrm{mol\,H_2O}}{1\,\mathrm{mol\,NaOH}}\right) = 0.1147\,\mathrm{mol\,H_2O}$$

HCH_3COO produces less H_2O, so HCH_3COO is the limiting reagent and 0.1064 mol H_2O is formed.

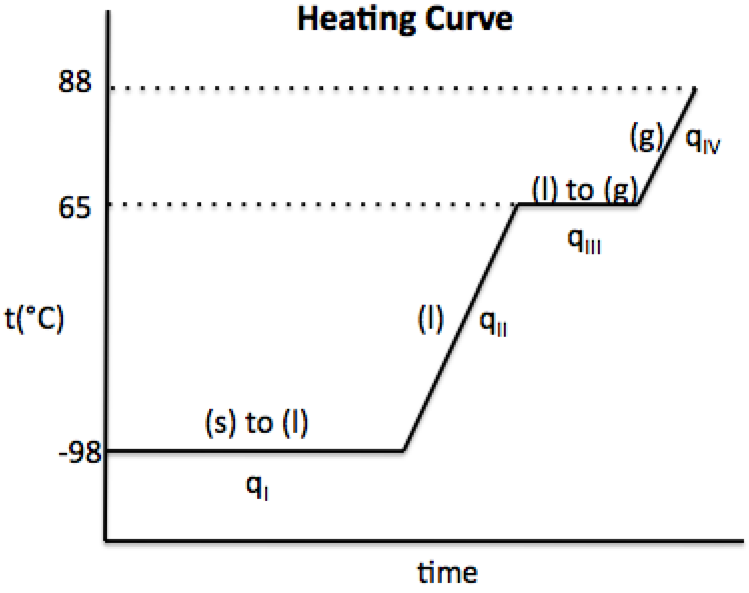
$$\Delta\mathrm{H} = \frac{-5.742\,\mathrm{kJ}}{0.1064\,\mathrm{mol\,H_2O}} = -54.0\,\mathrm{kJ/mol\,H_2O}$$

12

Consider the following data for methanol, CH_3OH:

melting point = -98°C
boiling point = 65°C
ΔH_{fusion} = 3.2 kJ/mol
$\Delta H_{\text{vaporization}}$ = 38 kJ/mol
specific heat of liquid methanol = 2.5 J/g·°C
specific heat of methanol vapor = 1.7 J/g·°C

Sketch a heating curve that depicts solid methanol at -98°C being heated to 88°C and then calculate the total amount of heat in kilojoules absorbed when 77 grams of methanol undergoes this process.



I) solid methanol at −98°C to liquid methanol at −98°C:

$$q_I = 77\,\text{g}\left(\frac{1\,\text{mol}}{32.04\,\text{g}}\right)\left(\frac{3.2\,\text{kJ}}{1\,\text{mol}}\right) = 7.69\,\text{kJ}$$

II) liquid methanol at −98°C to liquid methanol at 65°C:

$$q_{II} = 77\,\text{g}\left(\frac{2.5\,\text{J}}{\text{g}\cdot^{\circ}\text{C}}\right)(65-(-98))^{\circ}\text{C}\left(\frac{1\,\text{kJ}}{1000\,\text{J}}\right) = 31.4\,\text{kJ}$$

III) liquid methanol at 65°C to methanol vapor at 65°C:

$$q_{III} = 77\,\text{g}\left(\frac{1\,\text{mol}}{32.04\,\text{g}}\right)\left(\frac{38\,\text{kJ}}{1\,\text{mol}}\right) = 91.3\,\text{kJ}$$

IV) methanol vapor at 88°C to methanol vapor at 88°C:

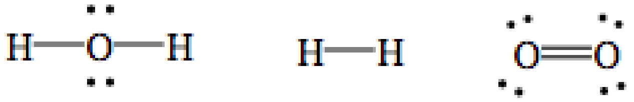
$$q_{\mathrm{IV}} = 77\,\mathrm{g}\left(\frac{1.7\,\mathrm{J}}{\mathrm{g}\cdot{}^{\circ}\mathrm{C}}\right)(88-65)^{\circ}\mathrm{C}\left(\frac{1\,\mathrm{kJ}}{1000\,\mathrm{J}}\right) = 3.01\,\mathrm{kJ}$$

$$q_{\mathrm{total}} = 7.69 + 31.8 + 91.3 + 3.01 = 133\,\mathrm{kJ}$$

13

Given the reaction $2H_2O(g) \longrightarrow 2H_2(g) + O_2(g)$ $\Delta H = 484\,\mathrm{kJ/mol}$, use the table of average bond energies to calculate the H−H bond energy.

Lewis structures:



$$\Delta H = (2x2)(O-H) - 2(H-H) - 1(O=O)$$

$$484\,\mathrm{kJ/mol} = 4(464\,\mathrm{kJ/mol}) - 2(H-H) - 1(498\,\mathrm{kJ/mol})$$

$$\text{bond energy of } H-H = 437 \text{ kJ/mol}$$

14

Given the reaction $2C_2H_2(g) + 5O_2(g) \longrightarrow 4CO_2(g) + 2H_2O(l)$ $\Delta H^{\circ} = -2602\,\mathrm{kJ/mol}$, use the information below to calculate the standard enthalpy of formation, ΔH_f°, for $C_2H_2(g)$:

Compound	ΔH_f° (kJ/mol)
$CO_2(g)$	-394
$H_2O(l)$	-286

$$\Delta H^{\circ} = -2602\,\mathrm{kJ/mol} = 4(-394\,\mathrm{kJ/mol}) + 2(-286\,\mathrm{kJ/mol}) - 2(\Delta H_f^{\circ}\text{ for } C_2H_2(g)) - 5(0\,\mathrm{kJ/mol})$$

$$\Delta H_f^{\circ}\text{ for } C_2H_2(g) = 227\,\mathrm{kJ/mol}$$

15

ΔH for the dissolving process $KClO_3(s) \longrightarrow KClO_3(aq)$ is $+41.4\,\mathrm{kJ/mol}$ $KClO_3$. In an insulated calorimeter, 14.1 grams of solid $KClO_3$ at 24.6°C was dissolved in 102.5 grams of water also at 24.6°C. If the specific heat of the mixed solution was 3.91 J/g·°C, determine the final temperature in the calorimeter.

$$q_{\text{rxn gained}} = 14.1\,\text{g}\,\text{KClO}_3\left(\frac{1\,\text{mol}\,\text{KClO}_3}{122.6\,\text{g}\,\text{KClO}_3}\right)\left(\frac{41.4\,\text{kJ}}{1\,\text{mol}\,\text{KClO}_3}\right)\left(\frac{1000\,\text{J}}{1\,\text{kJ}}\right) = 4761\,\text{J}$$

$$q_{\text{soln lost}} = -q_{\text{rxn gained}} = -4761\,\text{J} = (14.1 + 102.5)\,\text{g}\left(\frac{3.91\,\text{J}}{\text{g}\cdot^\circ\text{C}}\right)(t_{\text{final}} - 24.6^\circ\text{C})$$

$$t_{\text{final}} = 14.2^\circ\text{C}$$

16

Consider the reaction $\text{Sr(OH)}_2\text{(aq)} + 2\text{HNO}_3\text{(aq)} \longrightarrow 2\text{H}_2\text{O(l)} + \text{Sr(NO}_3)_2\text{(aq)}\ \ \Delta\text{H}^\circ = -112\,\text{kJ/mol}$. In an insulated calorimeter, 65.4 mL of 2.96 M strontium hydroxide at 22.5°C was mixed with 72.6 mL of 2.84 M nitric acid also at 22.5°C. If the density of the mixed solution was 1.06 g/mL and the specific heat of the mixed solution was 3.89 J/g·°C, determine the final temperature in the calorimeter.

$$65.4\,\text{mL}\left(\frac{1\,\text{L}}{1000\,\text{mL}}\right)\left(\frac{2.96\,\text{mol}\,\text{Sr(OH)}_2}{1\,\text{L}}\right)\left(\frac{2\,\text{mol}\,\text{H}_2\text{O}}{1\,\text{mol}\,\text{Sr(OH)}_2}\right) = 0.3872\,\text{mol}\,\text{H}_2\text{O}$$

$$72.6\,\text{mL}\left(\frac{1\,\text{L}}{1000\,\text{mL}}\right)\left(\frac{2.84\,\text{mol}\,\text{HNO}_3}{1\,\text{L}}\right)\left(\frac{2\,\text{mol}\,\text{H}_2\text{O}}{2\,\text{mol}\,\text{HNO}_3}\right) = 0.2062\,\text{mol}\,\text{H}_2\text{O}$$

HNO_3 produces less H_2O, so HNO_3 is the limiting reagent and 0.2062 mol H_2O is formed in the reaction.

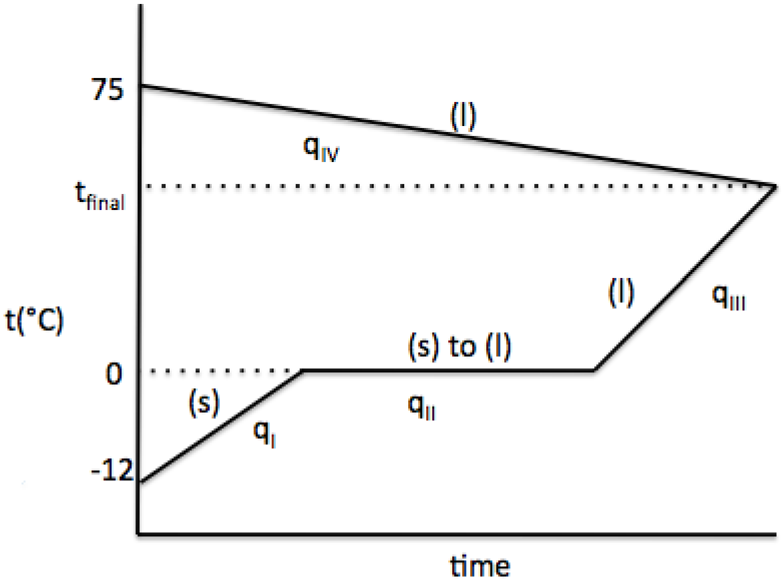
$$q_{\text{rxn lost}} = 0.2062\,\text{mol}\,\text{H}_2\text{O}\left(\frac{-112\,\text{kJ}}{2\,\text{mol}\,\text{H}_2\text{O}}\right)\left(\frac{1000\,\text{J}}{1\,\text{kJ}}\right) = -1.155\times 10^4\,\text{J}$$

$$q_{\text{soln gained}} = -q_{\text{rxn lost}} = 1.155\times 10^4\,\text{J} = (65.4 + 72.6)\,\text{mL}\left(\frac{1.06\,\text{g}}{1\,\text{mL}}\right)\left(\frac{3.89\,\text{J}}{\text{g}\cdot^\circ\text{C}}\right)(t_{\text{final}} - 22.5^\circ\text{C})$$

$$t_{\text{final}} = 42.8^\circ\text{C}$$

17

If 8.5 grams of ice at -12°C is added to an insulated calorimeter containing 65 grams of water at 75°C, and all the ice melts, sketch a heating/cooling curve for the process and determine the final temperature of the liquid water in the calorimeter.



I) ice at $-12°C$ to ice at $0°C$:

$$q_I = 8.5\,g\left(\frac{2.03\,J}{g\cdot^\circ C}\right)(0-(-12))^\circ C$$

II) ice at $0°C$ to liquid water at $0°C$:

$$q_{II} = 8.5\,g\left(\frac{1\,mol}{18.02\,g}\right)\left(\frac{6.01\,kJ}{1\,mol}\right)\left(\frac{1000\,J}{1\,kJ}\right)$$

III) liquid water at $0°C$ to liquid water at t_{final}:

$$q_{III} = 8.5\,g\left(\frac{4.18\,J}{g\cdot^\circ C}\right)(t_{final}-0^\circ C)$$

IV) liquid water at $75°C$ to liquid water at t_{final}:

$$q_{IV} = 65\,g\left(\frac{4.18\,J}{g\cdot^\circ C}\right)(t_{final}-75^\circ C)$$

$$q_I + q_{II} + q_{III} = -q_{IV},\ \text{solve for}\ t_{final}$$

:

$$t_{final} = 56^\circ C$$

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