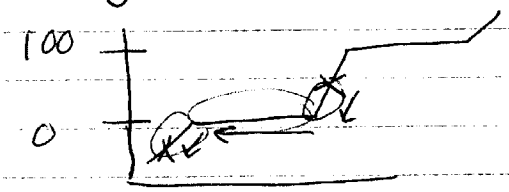
Blue

Answers to Supplemental Questions-
Heat involved in Phase Changes

1. 500. g $H_2O_{(l)}$ 25.0°C → ice @ -35.0°C



3 processes

① cool water 25.0°C → 0°C (exact 0 − 25.0)

$q = smΔT = (4.184\ J/g°C)(500.\ g)(-25.0°C)$

$q_1 = -52300\ J$

② freeze water @ 0°C ΔH⊖ phase change

$(500.\ g\ H_2O)\left(\frac{1\ mol\ H_2O}{18.016\ g\ H_2O}\right)\left(\frac{6.01\ kJ}{1\ mol}\right) = -166.8\ kJ$

③ cool ice 0° → -35.0°C (-35.0 − 0)

$q = smΔT = (2.03\ J/g°C)(500.\ g)(-35.0°C)$

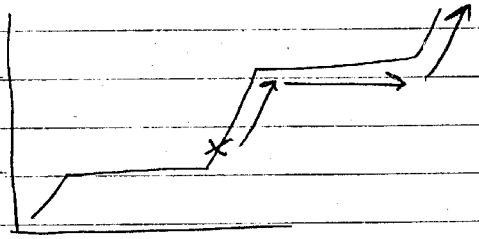
$q_3 = -35525\ J$

total: $-52.3\ kJ$
$-166.8\ kJ$
$-35.525\ kJ$

$-254.625\ kJ$ ⇒ **-255 kJ total**

2. 250. mL $H_2O_{(l)}$ 20.0°C → steam @ 200.0°C

3 processes



① heat water 20.0°C → 100°C

$q = smΔT$

$q_1 = (4.184\ J/g°C)(250.\ g)(80.0°C) = 83680\ J$

(2) boil water @ 100°C

$$(250.g)\left(\frac{1\ mol}{18.016g}\right)\left(\frac{40.79\ KJ}{1\ mol}\right) = 566\ KJ$$

(3) heat steam $\underset{exact}{100} \rightarrow 200.0°C$

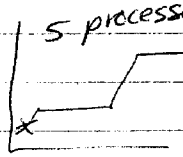
$$q = SM\Delta T = (1.99\ J/g·C)(250.g)(100.0°C)$$

$$q_3 = 49750\ J$$

add:

$$\begin{array}{r} 83.68\ KJ \\ +\ 566\ KJ \\ 49.75\ KJ \\ \hline 699.43\ KJ \end{array} \Rightarrow \text{699 KJ total}$$

3. 100.g ice -25.0°C → steam @ 180.0°C



(1) ice warms −25.0°C → 0°C

$$q_1 = SM\Delta T = (2.03\ J/g·C)(100.g)(25.0°C) = 5075\ J = 5.075\ KJ$$

(2) ice melts @ 0°C

$$(100.g)\left(\frac{1\ mol}{18.016g}\right)\left(\frac{6.01\ KJ}{1\ mol}\right) = 33.36\ KJ$$

(3) water warms 0°C → 100°C

$$q = SM\Delta T = (4.184\ J/g·C)(100.g)(100.°C) = 41840\ J = 41.84\ KJ$$

(4) water vaporizes @ 100°C

$$(100.g)\left(\frac{1\ mol}{18.016g}\right)\left(\frac{40.79\ KJ}{1\ mol}\right) = 226.4\ KJ$$

(5) steam warms 100 → 180.0°C

$$q = SM\Delta T = (1.99\ J/g·C)(100.g)(80.0°C) = 15920\ J = 15.92\ KJ$$

add
5.075 kJ
33.36 kJ
41.84 kJ
226.4 kJ
+ 15.92 kJ

322.595 kJ ⇒ 323 kJ total

4. 20.6 g steam @ 100°C + water @ 19.8°C
T_f = 75.3°C T_f = 75.3°C

① water warms from 19.8°C → 75.3°C q_1 ⊕

② steam condenses @ 100°C q_2 ⊖
③ hot water cools 100 → 75.3°C q_3 ⊖

$$q_1 = -(q_2 + q_3)$$

total heat for endothermic processes = − (total heat for exothermic processes)

$$q_1 = s m \Delta T = \left(4.184 \frac{J}{g^\circ C}\right)(m_w)(55.5\,^\circ C) = 232.2 m_w \text{ J/g}$$

(m_w: unknown; 75.3 − 19.8)

q_2 = (phase change)

$$(20.6\text{g steam})\left(\frac{1\text{ mol}}{18.016\text{g}}\right)\left(\frac{-40.79\text{ kJ}}{1\text{ mol}}\right) = -46.64\text{ kJ} \quad q_2$$

$$q_3 = s m \Delta T = \left(4.184 \frac{J}{g^\circ C}\right)(20.6\text{g})(-24.7\,^\circ C)$$

75.3 − 100

$$q_3 = -2128.9\text{ J}$$

$q_1 = -(q_2 + q_3)$

$(232.2\,m)\,J/g = -(-46640\,J - 2128.9\,J)$

$\frac{(232.2\,m)\,J/g}{232.2\,J/g} = \frac{-(-48768.9\,J)}{232.2\,J/g}$

$m = 210.\,g$ ~~steam~~ water

5. 125 mL H_2O @ 18.7°C + ice 0°C
$T_f = 12.5$ $T_f = 12.5°C$

① water cooling 18.7° → 12.5°C $q^{(-)}$

② ice melting @ 0°C $q^{(+)}$

③ ice water warming 0°C → 12.5°C $q^{(+)}$

total q endo = − (total q exo)

$q_2 + q_3 = -(q_1)$

1. $q_1 = smΔT = (4.184\,J/g{\cdot}°C)(125\,g)(-6.2°C)$ (12.5 − 18.7)

$q_1 = -3242.6\,J$

2. q_2

$m_{ice} \times \left(\frac{1\,mol}{18.016\,g}\right)\left(\frac{6.01\,kJ}{1\,mol}\right) = ^{(+)}0.3336\,m_{ice}\,kJ/g = q_2$

3. $q_3 = smΔT = (4.184\,J/g{\cdot}°C)(m_{ice})(12.5°C)$ (12.5 − 0) $= ^{(+)}52.3\,m_{ice}\,J/g$

→ $q_2 = 333.6\,m_{ice}\,J/g$ (make units consistent)

$q_2 + q_3 = -(q_1)$

$(333.6\, m_{ice}\ J/g) + (52.3\, m_{ice}\ J/g) = -(-3242.6\ J)$

$$\frac{385.9\, m_{ice}\ J/g}{385.9\ J/g} = \frac{3242.6\ J}{385.9\ J/g}$$

$$m_{ice} = 8.4\ g$$

6. 95.0 g H_2O 24.2°C + 10.0 g ice 0.°C

① water cooling q_1

$q_1 = smT\Delta = (4.184\ J/g\cdot°C)(95.0\ g)(T_f - 24.2°C)$

$= (397.5\, T_f)\ J/°C - 9619\ J$

② ice melting @ 0.0°C

$(10.0\ g)\left(\frac{1\ mol}{18.016\ g}\right)\left(\frac{6.01\ kJ}{1\ mol}\right) = 3.336\ kJ \Rightarrow 3336\ J$ q_2

③ ice warming $0° \rightarrow T_f$

$q = smT\Delta = (4.184\ J/g°C)(10.0\ g)(T_f - 0°C)$

$q_3 = (41.84\, T_f)\ J/°C - 0\ J$

$-(q_1) = q_2 + q_3$

$-[(397.5\, T_f)\ J/°C - 9619\ J] = 3336\ J + (41.84\, T_f)\ J/°C$

$(-397.5\, T_f)\ J/°C + 9619\ J = 3336\ J + (41.84\, T_f)\ J/°C$

$+397.5\, T_f \qquad -3336\ J \qquad -3336\ J \qquad +397.5\, T_f$

(6)

$$\frac{6283\ J}{(439.34\ J/^\circ C)} = \frac{(439.34\ T_f)\ J/^\circ C}{(439.34\ J/^\circ C)}$$

$$14.3^\circ C = T_f$$