AP® Chemistry
2003 Sample Student Responses
Form B

3A 1

3. In an experiment, a sample of an unknown, pure gaseous hydrocarbon was analyzed. Results showed that the sample contained 6.000 g of carbon and 1.344 g of hydrogen.

(a) Determine the empirical formula of the hydrocarbon.

(b) The density of the hydrocarbon at 25°C and 1.09 atm is 1.96 g L^{-1}.

(i) Calculate the molar mass of the hydrocarbon.

(ii) Determine the molecular formula of the hydrocarbon.

In another experiment, liquid heptane, $C_7H_{16}(l)$, is completely combusted to produce $CO_2(g)$ and $H_2O(l)$, as represented by the following equation.

$$C_7H_{16}(l) + 11\,O_2(g) \rightarrow 7\,CO_2(g) + 8\,H_2O(l) \quad \Delta H^\circ_{rxn} = -4.85\times10^3\ kJ$$

The heat of combustion, ΔH°_{comb}, for one mole of $C_7H_{16}(l)$ is -4.85×10^3 kJ.

(c) Using the information in the table below, calculate the value of ΔH°_f for $C_7H_{16}(l)$ in kJ mol^{-1}.

Compound	ΔH°_f (kJ mol^{-1})
$CO_2(g)$	−393.5
$H_2O(l)$	−285.8

(d) A 0.0108 mol sample of $C_7H_{16}(l)$ is combusted in a bomb calorimeter.

(i) Calculate the amount of heat released to the calorimeter.

(ii) Given that the total heat capacity of the calorimeter is 9.273 kJ °C^{-1}, calculate the temperature change of the calorimeter.

a – $n_C = 6.000\,g \left(\frac{1\,mol\,C}{12.011\,g}\right) = 0.4995\ mol\ C$

$n_H = 1.344\,g \left(\frac{1\,mol\,H}{1.0079\,g}\right) = 1.333\ mol\ H$

$\} \; C_{0.4995} H_{1.333} \Rightarrow C_{\frac{1}{2}} H_{\frac{4}{3}}$

$\Rightarrow$ C_3H_8 = empirical formula

b – $T = 273 + 25 = 298K$ $\quad d = 1.96\,g/L$ $\quad PV = nRT$

$P = 1.09\ atm$

i) Molar mass $= \frac{dRT}{P} = \frac{1.96\,g/L \times (0.08206\,\frac{L\cdot atm}{mol\cdot K})(298K)}{1.09\,atm}$

Molar mass = 43.97 g/mol

m m = 44.0 g/mol

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ii) Molecular formula:

$44.0g = k(3(12.011g) + 3(1.0079g))$

$44.0g = k\ 44.0962g$

$k = \frac{44.0g}{44.0961g} = 0.998 \approx 1$

Molecular formula is C_3H_8 since k is 1.

c) $-4.85 \times 10^3 KJ = (8mol \times (-285.8 KJ/mol) + 7mol(-393.5 KJ/mol)) - (0 + \Delta H^o_{f C_7H_{16}})$

$\Delta H^o_{f C_7H_{16}} = -2286.4KJ - 2754.5KJ + 4.85 \times 10^3 KJ$

$\Delta H^o_{f C_7H_{16}} = -190.9 KJ/1mol$

$\Delta H^o_{f C_7H_{16}} = -191 KJ/mol$

d) i) Heat released = $0.0108 mol C_7H_{16} \left(\frac{-4.85 \times 10^3 KJ}{1mol}\right) = -52.38 KJ$

Thus 52.4KJ released as heat ~~to the surroundings~~.

ii) $\Delta T = 52.4 KJ \left(\frac{1°C}{9.273 KJ}\right) = 5.6486°C$

$\Delta T = 5.65°C$

STOP

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3B 1

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(i) Calculate the amount of heat released to the calorimeter.

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a) C_xH_y → 6g C × $\frac{1n}{12g}$ = 0.5n C (0.5 : 1.344) ÷ 0.5

→ 1.344 × $\frac{1n}{1.0g}$ = 1.344 n H. (1 : 2.688) × 3

3 : 8.064 ≈ 3 : 8

↳ ∴ emp. formula = C_3H_8.

(b)(i) density = $\frac{1.96g}{1L}$ emp. weight = 3(12) + 8(1) = 44g.

Mp = n·mass = g/n

↳ @ STP, 1n gas/22.4L → $\frac{1.96g}{1L} \times \frac{22.4L}{1n}$ = 43.904 g/n

(ii) emp. weight = 44g.

↳ ratio (empirical weight : molecular weight) = 44 : 43.904

≈ 1 : 1

↳ ∴ molecular formula = C_3H_8.

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ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

c) $\Delta H_f^\circ = \Delta H(\text{product}) - \Delta H(\text{reactant})$ — $\Delta H_f(C_7H_{16})$

$-4.85\times10^3 = (7(-393.5)+8(-285.8)) - (X)$

$-4.85\times10^3 = -5040.9 - X$.

$-X = -4.85\times10^3 + 5040.9 = 190.9$

$X = -190.9\ \text{kJ/n} = \Delta H_f(C_7H_{16})$.

d) (i) $\Delta H_{comb} = -4.85\times10^3\ \text{kJ/n}$

↳ $\Delta H = 0.0108\text{n} \times -4.85\times10^3\ \text{kJ/n} = -52.38\ \text{kJ}$

(ii) $C_p = \frac{\Delta H}{\Delta T} = (-52.38\ \text{kJ}) / (X)$ — $X = \Delta T$.

↳ $X = \Delta H / C_p = (-52.38\ \text{kJ}) / (9.273\ \text{kJ/°C}) = -5.65\ \text{°C} = \Delta T$.

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3C1

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3. (a) H_xC_y (C_yH_x)

1.344 g 6.00 g

$n(C) = \frac{6.00}{12.011} = 0.5$ mol

C : H

$n(H) = \frac{1.344}{1.0079} = 1.34$ mol

= 0.5 : 1.34

= 1 : 2.68

= 5 : 13 C_5H_{13}

(b) (i) $PV = nRT$

$d = \frac{m}{V} = 1.96\ g/L$

$P\frac{m}{d} = \frac{m}{M_r}RT$

$M_r = RT \cdot \frac{d}{P}$

$= (0.0821)(25+273)\left(\frac{1.96}{1.09}\right) = 43.99 \approx 44.0$ g

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3C2

ADDITIONAL PAGE FOR ANSWERING QUESTION 3.

(ii) C_5H_{13} = 73 g

~~73 ÷ 44 =~~

44 ÷ 73 = 0.60 ≈ $\frac{3}{5}$

$C\ 5 \cdot \frac{3}{5}$: $H\ 13 \cdot \frac{3}{5}$

≈ C_3H_8

(c) $\Delta H^\circ_{comb} = [8(-285.8) + 7(-393.5)] - \Delta H^\circ_f\ C_7H_{16}$

$\Delta H^\circ_f\ C_7H_{16} = -5040.9 + 4.85 \times 10^3$

= −190.9 KJ/mol

(d)

(i) 1 : -4.85×10^3 KJ = 0.0108 : x

$\frac{1\ mol}{-4.85 \times 10^3 KJ}$, $\frac{x\ KJ}{0.0108\ mol}$ x = (0.0108)(-4.85×10^3)

= −52.38

≈ −52.4 KJ

x = 0.0108 ~~mol~~ $\frac{-4.85 \times 10^3 KJ}{1\ mol}$

(ii) q = mcΔT ΔH = heat released × $\frac{1}{mol}$

m(C_7H_{16}) ΔT = $\frac{q}{mC}$

= (0.0108)(100) 52.4 = heat released × $\frac{1}{0.0108}$

≈ 1.08 g = $\frac{0.566 KJ}{(1.08)(9.273 KJ/°C)}$ heat released = 0.566 KJ

= 0.0565 °C

STOP

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