AP Questions: Thermochemistry

1984 B

Substance	Standard Heat of Formation, ΔH_f^o in kJ mol^{-1}
$C(s)$	0.00
$CO_2(g)$	-393.5
$H_2(g)$	0.00
$H_2O(l)$	-285.85
$O_2(g)$	0.00
$C_3H_7COOH(l)$	?

The enthalpy change for the combustion of butyric acid at 25°C, ΔH_{comb}, is -2,183.5 kilojoules per mole. The combustion reaction is

$$C_3H_7COOH(l) + 5\ O_2(g) \rightarrow 4\ CO_2(g) + 4\ H_2O(l)$$

(a) From the above data, calculate the standard heat of formation, ΔH_f^o, for butyric acid.

(b) Write a correctly balanced equation for the formation of butyric acid from its elements.

1988 B

Substance	Enthalpy of Combustion, ΔH (kiloJoules/mol)
$C_{(s)}$	-393.5
$H_2(g)$	-285.8
$C_2H_5OH(l)$	-1366.7
$H_2O(l)$	- -

(a) Write a separate, balanced chemical equation for the combustion of each of the following: $C(s)$, $H_2(g)$, and $C_2H_5OH(l)$. Consider the only products to be CO_2 and/or $H_2O(l)$.

(b) In principle, ethanol can be prepared by the following reaction:

$$2\ C(s) + 2\ H_2(g) + H_2O(l) \rightarrow C_2H_5OH(l)$$

Calculate the standard enthalpy change, ΔH, for the preparation of ethanol, as shown in the reaction above.

1988 D

An experiment is to be performed to determine the standard molar enthalpy of neutralization of a strong acid by a strong base. Standard school laboratory equipment and a supply of standardized 1.00 molar HCl and standardized 1.00 molar NaOH are available.

(a) What equipment would be needed?

(b) What measurements should be taken?

(c) Without performing calculations, describe how the resulting data should be used to obtain the standard molar enthalpy of neutralization.

(d) When a class of students performed this experiment, the average of the results was -55.0 kilojoules per mole. The accepted value for the standard molar enthalpy of neutralization of a strong acid by a strong base is -57.7 kilojoules per mole. Propose two likely sources of experimental error that could account for the result obtained by the class.

1995 B

Propane, C_3H_8, is a hydrocarbon that is commonly used as fuel for cooking.

(a) Write a balanced equation for the complete combustion of propane gas, which yields $CO_2(g)$ and $H_2O(l)$.

(b) Calculate the volume of air at 30°C and 1.00 atmosphere that is needed to burn completely 10.0 grams of propane. Assume that air is 21.0 percent O_2 by volume.

(c) The heat of combustion of propane is -2,220.1 kJ/mol. Calculate the heat of formation,,ΔH_f^o, of propane given that ,ΔH_f^o of $H_2O(l)$ = -285.3 kJ/mol and ,ΔH_f^o of $CO_2(g)$ = -393.5 kJ/mol .

(d) Assuming that all of the heat evolved in burning 30.0 grams of propane is transferred to 8.00 kilograms of water (specific heat = 4.18 J/g·K), calculate the increase in temperature of water.

1998 B

$$C_6H_5OH(s) + 7\,O_2(g) \rightarrow 6\,CO_2(g) + 3\,H_2O(l)$$

When a 2.000-gram sample of pure phenol, $C_6H_5OH(s)$, is completely burned according to the equation above, 64.98 kilojoules of heat is released. Use the information in the table below to answer the questions that follow.

Substance	Standard Heat of Formation, ΔH_f^o; at 25°C (kJ/mol)
C*(graphite)*	0.00
$CO_2(g)$	-393.5
$H_2(g)$	0.00
$H_2O(l)$	-285.85
$O_2(g)$	0.00
$C_6H_5OH(s)$	?

(a) Calculate the molar heat of combustion of phenol in kilojoules per mole at 25°C.

(b) Calculate the standard heat of formation , ΔH_f^o, of phenol in kilojoules per mole at 25°C.

(c) If the volume of the combustion container is 10.0 liters, calculate the final pressure in the container when the temperature is changed to 110°C. (Assume no oxygen remains unreacted and that all products are gaseous.)

2001 B

$2\,NO(g) + O_2(g) \rightarrow 2\,NO_2(g)$ $\Delta H°= -114.1$ kJ, $\Delta S°= -146.5$ J K^{-1}

The reaction represented above is one that contributes significantly to the formation of photochemical smog.

(a) Calculate the quantity of heat released when 73.1 g of $NO(g)$ is converted to $NO_2(g)$.

(b) For the reaction at 25°C, the value of the standard free-energy change, $\Delta G°$, is -70.4 kJ.

(i) Calculate the value of the equilibrium constant, K_{eq}, for the reaction at 25°C.

(ii) Indicate whether the value of $\Delta G°$ would become more negative, less negative, or remain unchanged as the temperature is increased. Justify your answer.

(c) Use the data in the table below to calculate the value of the standard molar entropy, S°, for $O_2(g)$ at 25°C.

	Standard Molar Entropy, $S°$ (J K^{-1} mol^{-1})
$NO(g)$	210.8
$NO_2(g)$	240.1

(d) Use the data in the table below to calculate the bond energy, in kJ mol^{-1}, of the nitrogen-oxygen bond in NO_2 . Assume that the bonds in the NO_2 molecule are equivalent (*i.e.*, they have the same energy).

	Bond Energy (kJ mol^{-1})
Nitrogen-oxygen bond in NO	607
Oxygen-oxygen bond in O_2	495
Nitrogen-oxygen bond in NO_2	?