



## FREE-RESPONSE QUESTIONS

1. Butane ( $C_4H_{10}$ ), a gaseous hydrocarbon under standard conditions, is compressed into a liquid to be used as a fuel in disposable lighters.
- (a) Write a balanced equation with smallest whole number coefficients for the combustion of butane gas in excess oxygen, yielding products of carbon dioxide gas and liquid water.
- (b) Butane reacts with the oxygen gas in the air. Calculate the volume of air, measured at  $28^\circ C$  and 750. torr, required to complete the combustion of 2.00 g butane. The air in the atmosphere contains 20.9% oxygen by volume.
- (c) Use the values in the table of heats of formation to calculate the heat of formation for one mole of butane if its heat of combustion is  $-2877.5 \text{ kJ mol}^{-1}$ .

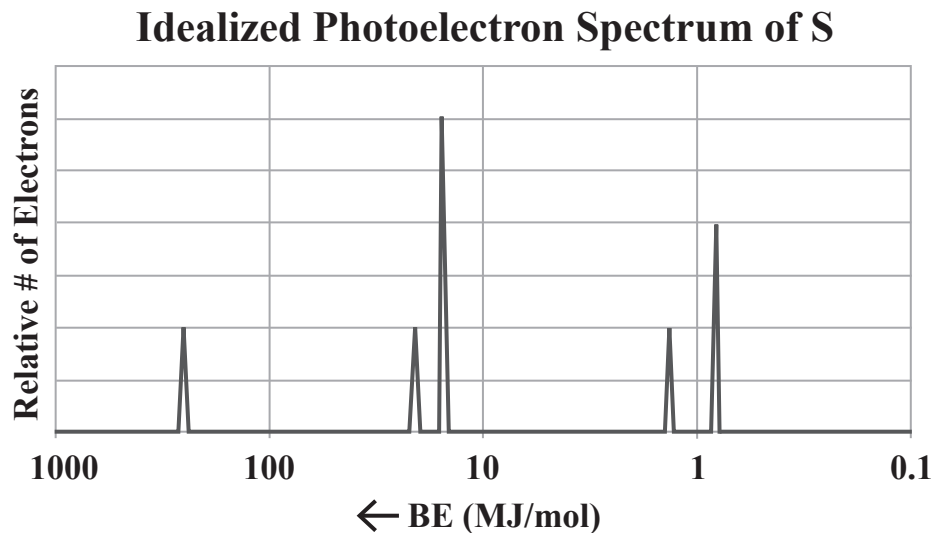
Substance	$\Delta H_f^\circ$ ( $\text{kJ mol}^{-1}$ )
$C_4H_{10}$	?
$CO_2$	-393.5
$H_2O(\ell)$	-285.8
$O_2$	0.0

- (d) Draw a Lewis structure for each reactant and product in the reaction.
- (e) Use the table of bond energies to calculate (an estimate of) the heat of combustion of butane.

Bond type	Bond energy ( $\text{kJ mol}^{-1}$ )
C-C	347
C=C	614
C-H	413
C-O	358
C=O (in $CO_2$ )	799
O-H	467
O=O	498



2. The (idealized) photoelectron spectrum of sulfur is shown in the plot below.



- (a) Label each of the peaks in the plot above with the orbital from which the photoelectrons came.
- (b) The most tightly bound electrons in sulfur have binding energy of 258.5 MJ/mol. What is the energy in electron volts (eV) of one of these electrons?  
(1 eV =  $1.602 \times 10^{-19}$  J, 1 MJ =  $1.0 \times 10^6$  J)
- (c) List two ways in which the photoelectron spectrum of the  $S^{2-}$  ion would differ from the photoelectron spectrum of atomic S.