Thermo Unit - Reaction Enthalpies

1. Use the following enthalpy data to calculate the reaction enthalpy for the combustion of methanol

$$2CH_3OH(l) + 3O_2(g) \longrightarrow 4H_2O(g) + 2CO_2(g)$$

$\Delta H_1 \quad C(s) + \frac{1}{2}O_2(g) + 2H_2(g) \longrightarrow CH_3OH(l) \qquad -239 \text{ kJ mol}^{-1}$

$\Delta H_2 \quad H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad -242 \text{ kJ mol}^{-1}$

$\Delta H_3 \quad C(s) + O_2(g) \longrightarrow CO_2(g) \qquad -393.5 \text{ kJ mol}^{-1}$

Work:

$-2\Delta H_1 \quad 2CH_3OH(l) \longrightarrow 2C(s) + O_2(g) + 4H_2(g) \qquad +478 \text{ kJ mol}^{-1}$

$4\Delta H_2 \quad 4H_2(g) + 2O_2(g) \longrightarrow 4H_2O(g) \qquad -968 \text{ kJ mol}^{-1}$

$2\Delta H_3 \quad 2C(s) + 2O_2(g) \longrightarrow 2CO_2(g) \qquad -787 \text{ kJ mol}^{-1}$

Final Answer:

$$2CH_3OH(l) + 3O_2(g) \longrightarrow 4H_2O(g) + 2CO_2(g) \qquad \Delta H = -1277 \ kJ \ mol^{-1}$$
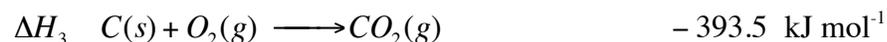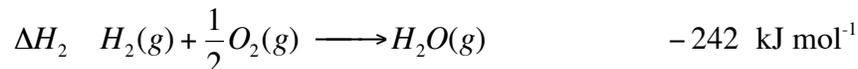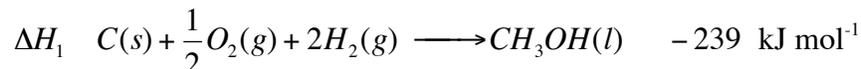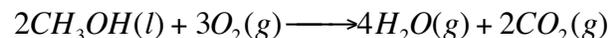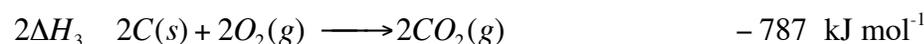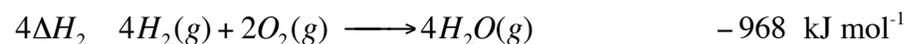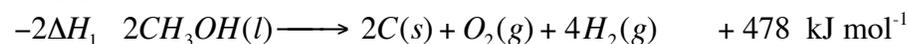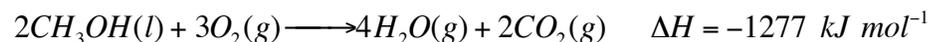
2. Use the enthalpies of formation from the table on the back to calculate the enthalpy for this same reaction.

Work:

$\Delta H_r = \sum Products - \sum Reactants$

$\Delta H_r = [4(\Delta H_{H_2O}) + 2(\Delta H_{CO_2})] - [2(\Delta H_{CH_3OH})]$

$\Delta H_r = [4(-241.8) + 2(-393.5)] - [2(-238.6)] = -1277 \text{ kJ mol}^{-1}$

3. Use the bond energy table on the back to calculate the enthalpy for this same reaction.

Reactants	Products
3 C-H = 3(413 kJ/mol) = 1239 kJ/mol	2 O-H = 2(463 kJ/mol) = 926 kJ/mol **x4 =**
1 C-O = 1(358 kJ/mol) = 358 kJ/mol	**3704 kJ/mol**
1 O-H = 1(463 kJ/mol) = 463 kJ/mol	2 C=O = 2(799 kJ/mol) = 1598 kJ/mol **x2 =**
All so far x2 = 4120 kJ/mol	**3196 kJ/mol**
3 O₂ = 3(495 kJ/mol) = 1485 kJ/mol	**TOTAL = 6900 kJ/mol**
TOTAL = 5605 kJ/mol	

More Work:

$\Delta H_r = \sum Reactants - \sum Products$

$\Delta H_r = [5605 kJ/mol] - [6900 \text{ kJ/mol}] = -1295 \text{ kJ mol}^{-1}$

TABLE 5.3 Standard Enthalpies of Formation, ΔH_f°, at 298 K

Substance	Formula	ΔH_f° (kJ/mol)	Substance	Formula	ΔH_f° (kJ/mol)
Acetylene	$C_2H_2(g)$	226.7	Hydrogen chloride	$HCl(g)$	−92.30
Ammonia	$NH_3(g)$	−46.19	Hydrogen fluoride	$HF(g)$	−268.6
Benzene	$C_6H_6(l)$	49.04	Hydrogen iodide	$HI(g)$	25.9
Calcium carbonate	$CaCO_3(s)$	−1207.1	Methane	$CH_4(g)$	−74.85
Calcium oxide	$CaO(s)$	−635.5	Methanol	$CH_3OH(l)$	−238.6
Carbon dioxide	$CO_2(g)$	−393.5	Propane	$C_3H_8(g)$	−103.85
Carbon monoxide	$CO(g)$	−110.5	Silver chloride	$AgCl(s)$	−127.0
Diamond	$C(s)$	1.88	Sodium bicarbonate	$NaHCO_3(s)$	−947.7
Ethane	$C_2H_6(g)$	−84.68	Sodium carbonate	$Na_2CO_3(s)$	−1130.9
Ethanol	$C_2H_5OH(l)$	−277.7	Sodium chloride	$NaCl(s)$	−411.0
Ethylene	$C_2H_4(g)$	52.30	Sucrose	$C_{12}H_{22}O_{11}(s)$	−2221
Glucose	$C_6H_{12}O_6(s)$	−1260	Water	$H_2O(l)$	−285.8
Hydrogen bromide	$HBr(g)$	−36.23	Water vapor	$H_2O(g)$	−241.8

Average Bond Enthalpies (kJ/mol)

Single Bonds

C—H	413	N—H	391	O—H	463		
C—C	348	N—N	163	O—O	146		
C—N	293	N—O	201	O—F	190		
C—O	358	N—F	272	O—Cl	203		
C—F	485	N—Cl	200	O—I	234		
C—Cl	328	N—Br	243				
C—Br	276			S—H	339		
C—I	240	H—H	436	S—F	327		
C—S	259	H—F	567	S—Cl	253		
		H—Cl	431	S—Br	218		
Si—H	323	H—Br	366	S—S	266		
Si—Si	226	H—I	299				
Si—C	301						
Si—O	368						

Multiple Bonds

C=C	614	N=N	418	O_2	495
C≡C	839	N≡N	941		
C=N	615			S=O	523
C≡N	891			S=S	418
C=O	799				
C≡O	1072				