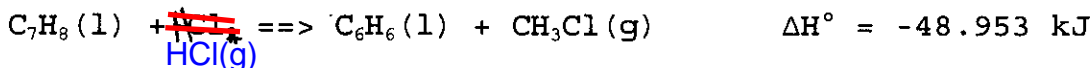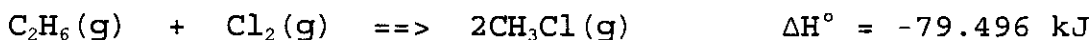# Hess' Law

3. Using Hess' Law find the heat of formation of toluene, $C_7H_8(l)$ given:

$C_6H_6(l)$ + $6H_2(g)$ ==> $3C_2H_6(g)$ $\Delta H° = -336.393$ kJ

$C_2H_6(g)$ + $Cl_2(g)$ ==> $2CH_3Cl(g)$ $\Delta H° = -79.496$ kJ

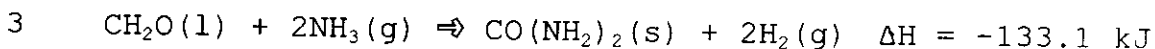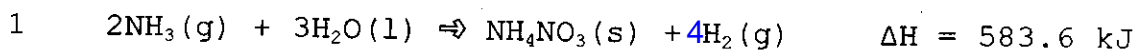$C_7H_8(l)$ + ~~H~~ HCl(g) ==> $C_6H_6(l)$ + $CH_3Cl(g)$ $\Delta H° = -48.953$ kJ
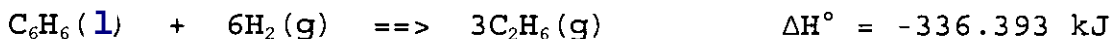
The heat of formation of ethane, $C_2H_6(g)$ is -84.517 kJ

The heat of formation of HCl(g) is -92.048 kJ

If I haven't made a mistake you should be able to check your answer using the tables in the back of the text. Don't forget the conversion to kcal!!!

4. Determine the heat of formation of urea, $CO(NH_2)_2$ using Hess' law from the information given below.
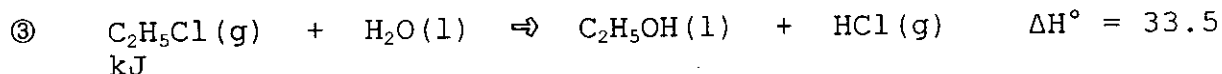
1   $2NH_3(g) + 3H_2O(l) \Rightarrow NH_4NO_3(s) + 4H_2(g)$ $\Delta H = 583.6$ kJ

2   $CH_2O(l) \Rightarrow CO(g) + H_2(g)$ $\Delta H = -1.9$ kJ

3   $CH_2O(l) + 2NH_3(g) \Rightarrow CO(NH_2)_2(s) + 2H_2(g)$ $\Delta H = -133.1$ kJ

4, 5 & 6 heats of formation of ~~$CO_2(g)$~~ CO(g), $H_2O(l)$ and $NH_4NO_3(s)$ are ~~-393.5 kJ~~ -110.5 kJ, -285.8 kJ and -583.6 kJ respectively

If this question has been written correctly (i.e. Schlank didn't make a mistake, the answer should be ~~-33.5 kJ~~ -551.5 kJ

7. Use Hess' Law to find the heat of formation of ethane (C_2H_6) given:

① $C_2H_6(g)$ + $\frac{1}{2}Cl_2(g)$ $\Rightarrow$ $C_2H_5Cl(g)$ + $\frac{1}{2}H_2(g)$ $\Delta H° = 8.6$ kJ
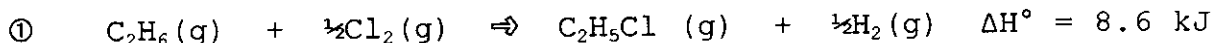
②   The heat of combustion of ethanol is -1409.2 kJ.

③ $C_2H_5Cl(g)$ + $H_2O(l)$ $\Rightarrow$ $C_2H_5OH(l)$ + $HCl(g)$ $\Delta H° = 33.5$ kJ

④   The heat of formation (and reaction thereof) for carbon dioxide gas.

⑤   The heat of formation (and reaction thereof) for water.

⑥   The heat of formation (and reaction thereof) for hydrogen chloride gas.

See text book for heats of formation and the answer!!

5.   ~~Use Hess' Law to determine the heat of formation of~~
     ~~p-nitrotoluene ($C_7H_7O_2N$) given:~~

     $C_7H_8(l) + HNO_3(l) ==> C_7H_7O_2N(l) + H_2O(l)$ $\Delta H = -47.25$ kcal

     ~~$C_7H_8(l) + 9O_2(g) ==> 7CO_2(g) + 4H_2O(l)$ $\Delta H = -943.1$ kcal~~

     $NO_2(g) + H_2O(l) ==> HNO_3(l) + H_2(g)$ $\Delta H = 18.8$ kcal
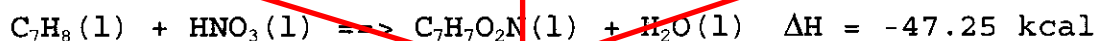
     ~~Table values for the formation reactions of $CO_2(g)$, $H_2O(l)$~~
     ~~and $NO_2(g)$~~

4.   Use Hess' Law (The Law of Hess) to prove that the heat of
     formation of ethyl alcohol (C_2H_5OH (l)) is -66.4 kcal/mol,
     using:
a)   The combustion of dimethyl ether (CH_3OCH_3 (l)) has a heat of
     reaction of $\Delta H = -348.6$ kcal
b)   The straight conversion (i.e. no other compounds present in
     the reaction) of dimethyl ether (CH_3OCH_3 (l)) to ethyl
     alcohol (C_2H_5OH (l))has a heat of reaction of -22.1 kcal
c)   the formation reaction for $CO_2(g)$
d)   the formation reaction for $H_2O(l)$
     Please write out all four equations and the equation for the
     formation of ethyl alcohol **before** you attempt the Hessian
     Law!

4.   Using Hess' Law, determine the heat of formation of
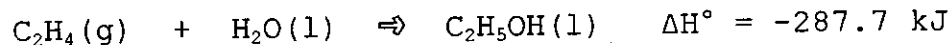   acetamide (CH_3CONH_2) from the following information:
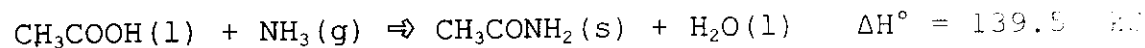
①   the oxidation of ethyl alcohol produces acetic acid

     $C_2H_5OH(l) + \frac{1}{2}O_2(g) \Rightarrow CH_3COOH(l) + H_2(g)$ $\Delta H° = -197.6$ kJ
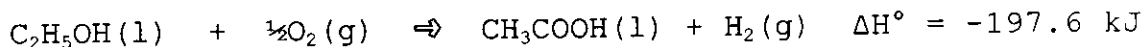
②   ethane can be formed from the addition of hydrogen to ethene

     $C_2H_4(g) + H_2(g) \Rightarrow C_2H_6(g)$ $\Delta H° = -136.3$ kJ
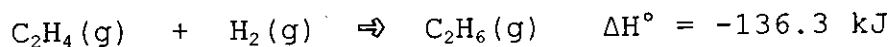
③   addition of water to ethene produces ethane

     $C_2H_4(g) + H_2O(l) \Rightarrow C_2H_5OH(l)$ $\Delta H° = -287.7$ kJ

④   acetic acid plus ammonia forms acetamide plus water

     $CH_3COOH(l) + NH_3(g) \Rightarrow CH_3CONH_2(s) + H_2O(l)$ $\Delta H° = 139.5$

⑤   formation of ammonia gas ($NH_3(g)$) (use text book)

⑥   formation of ethane gas ($C_2H_6(g)$) (use text book)

⑦   formation of water ($H_2O(l)$) (use text book)

5. Using Hess' Law determine heat of formation of urea $\underset{H_2N \quad NH_2}{\overset{O}{\diagdown}}$ from the following information:

① the heat of formation of ammonia ($NH_3(g)$) is -45.9 kJ

② the heat of combustion of acetic acid $\underset{OH}{\overset{O}{\diagdown}}$ (l) is -925.8 kJ

③ the heat of formation of methane ($CH_4(g)$) is -74.4

④ $\underset{H_2N \quad NH_2}{\overset{O}{\diagdown}}$ (l) + $H_2O(l)$ + $CH_4(g)$ $\Rightarrow$ $\underset{OH}{\overset{O}{\diagdown}}$ (l) + $2NH_3(g)$ $\Delta H° = 169.1$ kJ

⑤ the heat of formation of $CO_2(g)$ is -393.5 kJ

⑥ the heat of formation of H_2O (l) is -285.8 kJ

$\underset{H_2N \quad OH}{\overset{O}{\diagdown}}$

$\underset{H_2N \quad NH_2}{\overset{O}{\diagdown}}$

$\underset{Cl \quad OH}{\overset{O}{\diagdown}}$
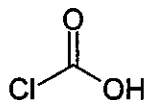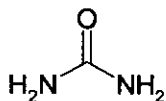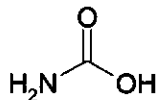
4. Calculate the heat of formation of NH_4Cl using the following equations and Hess' Law (ignore states).

		ΔH	
1.	$NH_3 + HCl == NH_4Cl$	$\Delta H = -176.73$ kJ
2.	$N_2 + 3H_2 == 2NH_3$	$\Delta H = -92.30$ kJ
3.	$2HCl + I_2 == 2HI + Cl_2$	$\Delta H = 236.23$ kJ
4.	$H_2 + I_2 == 2HI$	$\Delta H = 51.80$ kJ