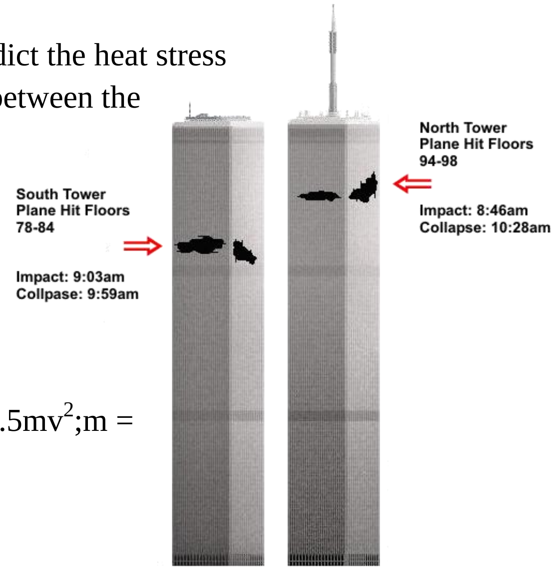
Chem Review Questions for June 2010

After the attacks of September 11, 2001, investigators had to predict the heat stress which the tower's steel had to endure as a result of the collision between the plane and the tower and the ensuing fire of all the fuel aboard. Especially important was the stress of the supportive but poorly fireproofed truss steel supports that collapsed and led to a domino effect in bringing down each tower. We will consider only one plane since only one plane crashed into each tower of the World Trade Center.



We will assume that all of the energy of the plane's motion(E_k=$0.5mv^2$;m = mass in kg and v = velocity in m/s) was converted into heat.

Total mass of **Boeing 707-320** = 148979 kg

Speed upon collision = 960 km/h

In addition we have to consider the additional heat released from the combustion of jet fuel. The mass of unused fuel on board each plane = 31632.65 kg. Although jet fuel consists of a mixture of alkanes with 9 to 17 carbons, we will use the average number in the following equation to reveal how much heat is released by the combustion of jet fuel:

$C_{13}H_{28(g)} + 20\ O_{2(g)} \rightarrow 13\ CO_{2(g)} + 14\ H_2O_{(g)}$

Given:

$C_{13}H_{28(g)} + 20\ O_{2(g)} \rightarrow 13\ CO_{2(g)} + 14\ H_2O_{(l)}$ + 8486 kJ

$H_2O_{(g)} \rightarrow H_2O_{(l)}$ $\Delta H = -41$ kJ

Facts about Steel	
Weight of steel tresses in the area near the impact of the plane	51020 kg
specific heat	450 J/(kg^{o}C)
Increase in temperature needed to deform steel tress supports	600^{o}C

Questions: a)Was the change in temperature that the steel experienced enough to stress the steel? Assume that only 1% of the energy from the plane's motion and combustion of fuel was absorbed by the steel tresses.

b) Why does a 600 ^oC increase in temperature stress the steel even though it does not melt it?

Answer: m =148979 kg
v = 960 km/h(1000m/km)(1h/3600 s) = **266.67 m/s**

$E_k = 0.5mv^2$
= 0.5(148979 kg)(266.67 m/s)^2
= 5.297 X 10^9 J = 5.297 X 10^6 kJ

For the energy released by the fuel:

To get the target equation $C_{13}H_{28(g)} + 20\ O_{2(g)} \rightarrow 13\ CO_{2(g)} + 14\ H_2O_{(g)}$ we need to combine:

$C_{13}H_{28(g)} + 20\ O_{2(g)} \rightarrow 13\ CO_{2(g)} + 14\ H_2O_{(l)}$ + 8486 kJ, which means ΔH = - 8486 kJ with

$14\ H_2O_{(l)} \rightarrow 14\ H_2O_{(g)}$ ΔH = 14(+41)kJ

(notice we've reversed the 2nd equation and multipled it by 14 to get ***liquid*** water to cancel)

Overall : $C_{13}H_{28(g)} + 20\ O_{2(g)} \rightarrow 13\ CO_{2(g)} + 14\ H_2O_{(g)}$ ΔH = -7912 kJ

From $C_{13}H_{28} + 20\ O_2 \rightarrow 13\ CO_2 + 14\ H_2O$ + 7912 kJ, we notice that each mole of $C_{13}H_{28}$ releases 7912 kJ. But we had more than 1 mole burning:

m = 31632.65 kg
31632.65 kg = 31 632 650 g of $C_{13}H_{28}$
31 632 650 g of $C_{13}H_{28}$ / (184 g/mole) = 171917 moles

171917 moles* 7912 kJ/mole = 1 360 207 304 kJ

Total amount of heat = chemical energy + kinetic energy
=1 360 207 304 kJ + 5.297 X 10^6 kJ = 1365504304kJ
= 1 365 504 304 000 J(we need joules for the next formula)

The tresses only absorbed 1% of the heat: 0.01(1 365 504 304 000) =
13655043040 J
$Q = mc\Delta T$
13655043040 J= 51020 kg *450 J/(kg^{o}C)(ΔT)^{o}C

= 595 ^{o}C

ΔT = 595^{o}C , very close to 600 ^{o}C (is equal if you consider significant figures = 6.0 X 10^2, so yes, the steel tresses would have been stressed. We are also ignoring all the heat released by everything else that burnt!

b) The vibrational energy of the iron(main atom in steel) will increase significantly and the bonds between the solid atoms will weaken to the point that they will bend out of shape and not support the concrete from the floor above.