How Hot can it Get (Thermo Review)

I can...

- ☐ distinguish the difference between heat (q) and temperature (T).
- ☐ describe the law of conservation of energy
  - Identify different forms of heat transfers
- ☐ define energy with appropriate units.
  - Identify different forms of energy
- ☐ define the universe in terms of the system and the surroundings
- ☐ describe and label the direction of heat flow in relation to the system using correct terminology and signage.
  - define exothermic and endothermic and assign correct signs.
- ☐ define specific heat (c) with appropriate units.
- ☐ calculate the amount of heat within a system when a temperature change is present ($q=mc\Delta T$).
- ☐ calculate the amount of heat required to change the phase of a substance.
- ☐ calculate the amount of heat transferred from one system to another and other related problems (ex. Calculate the final temperature).
- ☐ define enthalpy (ΔH) and the units of enthalpy.
- ☐ define enthalpy of formation.
- ☐ calculate the enthalpy of reaction using enthalpy of formations.
- ☐ identify on a heating curve or cooling curve where a phase change is occurring.
- ☐ calculate the amount of energy required to heat a substance from T_1 to T_2, (don't forget the phase changes).
- ☐ describe how the heat of a reaction changes as the reaction is manipulated (if the reaction is doubled the heat doubles)
- ☐ describe Hess's Law
- ☐ calculate the heat of a reaction using Hess's law and a reaction mechanism.
  - Identify a catalyst
  - Identify an intermediate

1. When solid barium hydroxide octahydrate is mixed with solid ammonium chloride in a glass flask, the flask gets cold.

a) Is the reaction absorbing or releasing heat? absorbing heat
b) Is the reaction endothermic or exothermic? endothermic (q_{rxn} = + value)
c) Why does the flask get cold?

The reaction (= system) absorbs heat from the surroundings (= the flask). Since you are in contact with the surroundings, you feel a drop in temperature as its heat is lost to the reaction.

2. How much heat is released when 620 g of iron drops in temperature from 80.6°C to 46.2°C?

$q_{Fe} = m C_{Fe} \Delta T$

$= 620\,g \cdot 0.444\,J/g\cdot°C \cdot (46.2°C - 80.6°C)$

$= \boxed{-9.5 \times 10^3\,J}$

Substance	Specific heat (J/g · °C)
Al	0.900
Au	0.129
C (graphite)	0.720
C (diamond)	0.502
Cu	0.385
Fe	0.444
Hg	0.139
$H_2O_{(l)}$	4.184
$H_2O_{(s)}$	2.108
$H_2O_{(g)}$	1.996
C_2H_5OH (ethanol)	2.46
H_{fus} of water = 333.4 J/g	
H_{vap} of water = 2256 J/g	

3. If 7270 J were added to 142 g of ethanol, how much would its temperature increase? (Solve for ΔT)

$\Delta T = \dfrac{q_{ethanol}}{[m \cdot C_{ethanol}]} = \dfrac{7270\,J}{[142\,g \cdot 2.46\,J/g\cdot°C]}$

$\Delta T = \boxed{20.8\,°C}$

4. 15 pieces of lead shot, each weighing 3.00 g, are placed in 40.0 g of water at room temperature (22.1°C). How much heat will it take to raise the temperature of the lead and water to 65.8°C?

$C_{Pb} = 0.127\,J/g\cdot°C$

$m_{Pb} = 15\,pcs \times 3.00\,g/pc = 45.0\,g$ $\quad \Delta T = 65.8°C - 22.1°C = 43.7°C$

$m_{H_2O} = 40.0\,g$

$q_{Total} = q_{Pb} + q_{H_2O} = [m_{Pb} \cdot C_{Pb} \cdot 43.7°C] + [m_{H_2O} \cdot C_{H_2O} \cdot 43.7°C]$

$= [45.0\,g \cdot 0.127\,J/g\cdot°C \cdot 43.7°C] + [40.0\,g \cdot 4.184\,J/g\cdot°C \cdot 43.$

$= \boxed{7.56 \times 10^3\,J \text{ or } 7560\,J}$

5. What mass of 58.0°C iron must be added to 342 g of 23°C ethanol to make the final temperature of both come out to be 40.0°C?

$-q_{Fe} = q_{ethanol}$

$-[m_{Fe} \cdot C_{Fe} \cdot (40.0°C - 58.0°C)] = [m_{ethanol} \cdot C_{ethanol} \cdot (40.0°C - 23°C)]$

$-[m_{Fe} \cdot 0.444\,J/g\cdot°C \cdot (-18.0°C)] = [342\,g \cdot 2.46\,J/g\cdot°C \cdot (17°C)]$

$m_{Fe} = \dfrac{[342\,g \cdot 2.46\,J/g\cdot°C \cdot (17°C)]}{-[0.444\,J/g\cdot°C \cdot (-18.0°C)]} = \boxed{1.8 \times 10^3\,g \text{ or } 1800\,g}$

6. 120.0 g of water at 20.0°C is mixed with 200.0 grams of aluminum at 50.0°C. What will the final temperature of both come out to be?

$-q_{Al} = q_{H_2O}$

$-[200.0\,g \cdot 0.900\,J/g\cdot°C \cdot (T_F - 50.0°C)] = [120.0\,g \cdot 4.184\,J/g\cdot°C \cdot (T_F - 20.0$

$-180\,J/°C\,(T_F - 50.0°C) = 502.08\,J/°C \cdot (T_F - 20.0°C)$

$-180\,T_F + 9000 = 502.08\,T_F - 10041.6$

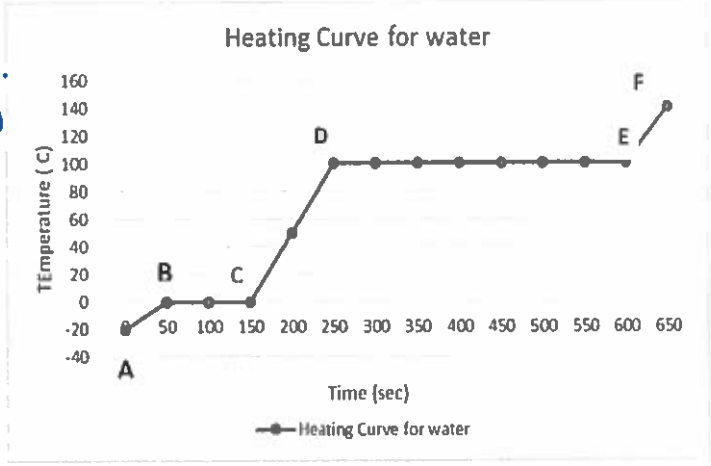
$-682.08\,T_F = -19041.6$ $\quad \therefore \boxed{T_F = 27.9°C}$

7. List the endothermic phase changes: – Melting
– vaporizing

8. List the exothermic phase changes: – freezing
– condensing

9. During a phase change why does the temperature not increase?

Average kinetic energy is unchanged. Only potential energy changes during phase changes.



10. Between what two points does melting (fusion) occur for this substance?

Between pts B and C.

11. Between what two points is this substance in liquid phase?

Between pts C and D.

12. Between what two points could the heat of vaporization for this substance measured?

Between pts D and E.

13. Between what two points is this substance in solid phase?

Between pts A and B.

14. How much heat was required to heat 50 grams of water from A to E?

① between pts A and B

$q_{ice} = m \cdot C_{ice} \cdot \Delta T$

$= (50g) \cdot 2.092\ J/g \cdot °C \cdot 20°C$

$= 2 \times 10^3\ J$

② between pts B and C

$q_{melt} = m \cdot H_{fus}$

$= 50g \cdot 333.4\ J/g$

$= 2 \times 10^4\ J$

③ between pts C and D

$q_{H_2O} = m \cdot C_{H_2O\ liq} \cdot \Delta T$

$= 50g \cdot 4.184\ J/g \cdot °C \cdot 100°C$

$= 2 \times 10^4\ J$

④ between pts D and E

$q_{boil} = m \cdot H_{vap}$

$= 50g \cdot 2256\ J/g$

$= 1 \times 10^5\ J$

⑤ between pts E and F

$q_{steam} = m \cdot C_{steam} \cdot \Delta T$

$= 50g \cdot 2.008\ J/g \cdot °C \cdot 40°$

$= 4 \times 10^3\ J$

$q_{total} = q_① + q_② + q_③ + q_④ + q_⑤$

$= \boxed{2 \times 10^5\ J}$

15. How much heat in joules does it take to vaporize 0.5000 L of H_2O at 100.°C (D_{water}=1 g/ml)

↳ 500.0 mL = 500.0 g

$q_{boil} = m_{H_2O} \cdot H_{vap}$

$= 500.0g \cdot 2256\ J/g$

$= \boxed{1.128 \times 10^6\ J}$

16. How much heat in kilojoules is released when 12.90 mL of H_2O freezes at 0°C?

$q_{freeze} = m \cdot H_{fus}$ (q will be −)

$q_{freeze} = 12.90\,g \cdot 333.4\,J/g = 4301\,J = 4.301\,kJ$

$q = -4.301\,kJ$

17. How much total heat in joules is given off if 26.0 g of H_2O at 42.0°C is frozen into ice, and then the temperature of the ice is lowered to -6.00°C? ($T_F - T_i$)

$q_{total} = -(m \cdot H_{fus}) + [m \cdot C_{ice} \cdot (-6.00°C - 0)]$

$= -(26.0\,g \cdot 333.4\,J/g) + [26.0\,g \cdot 2.092\,J/g \cdot °C \cdot (-6.00°C)]$

$= -8.99 \times 10^3\,J$

18. A sugar cookie has a total mass of 86.0 grams. In a constant volume (bomb) calorimetry experiment, a 1.0 g sample of this cookie was burned in a steel bomb surrounded by 1000 g of water. The temperature of the water in contact with the burning cookie was measured and found to increase from an initial temperature of 21.2°C to a final temperature of 25.7°C. Calculate the amount of calories (kcal) in the entire cookie. What is the caloric content in terms of Cal/g?

Caloric content $= \frac{4.11 \times 10^2\,kcal}{86.0\,g} = 4.78\,Cal/g$

$-q_{sample} = q_{H2O} = [1000\,g \cdot 4.184\,J/g \cdot °C \cdot (25.7°C - 21.2°C)]$

$q_{H2O} = 2 \times 10^4\,J$; $q_{sample} = -2 \times 10^4\,J$

kcal in 1 cookie $= \frac{86.0\,g}{1.0\,g\ sample} \left| \frac{2 \times 10^4\,J}{4.184\,J} \right| \frac{1\,cal}{1000\,cal} \left| \frac{1\,kcal}{} \right. = 4.11 \times 10^2\,kcal$

19. Calculate the heat of formation of glucose. (* use your ref. table)

$\Delta H_c = -2803.0\,kJ/mol$ (from table)

$C_6H_{12}O_6\,(s) + 3\,O_2\,(g) \rightarrow 6\,CO_2\,(g) + 6\,H_2O\,(l)$ (x, 0)

$\Delta H_c = -2803.0\,kJ = \Sigma H°_f\ products - \Sigma H°_f\ reactants$

$-2803.0\,kJ = [6\,mol(-393.5\,kJ/mol) + 6mol(-285.8\,kJ/mol)] - [x(1\,mol)]$

$x = H°_f\ of\ C_6H_{12}O_6 = -1273\,kJ/mol$

20. Calculate the heat of formation for phosphoric Acid. ($H°_f$ values are always kJ/mol)

$H_2O\,(l) + P_2O_5\,(s) \rightarrow H_3PO_4\,(aq)$ (x) $\quad \Delta H = 1290.4\,kJ$

$\Delta H = 1290.4\,kJ = \Sigma H°_f\ products - \Sigma H°_f\ reactants$

$1290.4\,kJ = [x] - [1\,mol(-285.8\,kJ/mol) + 1\,mol(-3009.9\,kJ/mol)]$

$x = H°_f\ of\ H_3PO_4 = -2005.3\,kJ/mol$

21. Find the ΔH for the reaction below, given the following steps and subsequent ΔH values:

$C_2H_2\,(g) + 5/2\,O_2\,(g) \rightarrow 2\,CO_2\,(g) + H_2O\,(g)$

need to:

(1) $C_2H_6\,(g) \rightarrow C_2H_2\,(g) + 2\,H_2\,(g)$ $\quad \Delta H = 283.5\,kJ$

(2) $H_2(g) + ½\,O_2\,(g) \rightarrow H_2O\,(g)$ $\quad \Delta H = -213.7\,kJ$

(3) $2CO_2\,(g) + 3H_2O\,(g) \rightarrow C_2H_6\,(g) + 7/2\,O_2\,(g)$ $\quad \Delta H = 849\,kJ$

flip (1) $C_2H_2(g) + 2H_2(g) \rightarrow C_2H_6(g)$ $\quad \Delta H = -283.5\,kJ$

Flip, ×2 (2) $2H_2O(g) \rightarrow 2H_2(g) + O_2(g)$ $\quad \Delta H = +213.7\,kJ \times 2$ (H_2O left)

flip (3) $C_2H_6(g) + 7/2\,O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ $\quad \Delta H = -849\,kJ$ ($5/2\,O_2$)

$C_2H_2(g) + 5/2\,O_2(g) \rightarrow 2CO_2(g) + H_2O(g)$ $\quad \Delta H_{rxn} = -705\,kJ$

22. Find the ΔH for the reaction below, given the following steps and subsequent ΔH values:

$HCl\ (g) + NaNO_2\ (g) \rightarrow HNO_2\ (g) + NaCl\ (s)$

$2\ NaCl\ (s) + H_2O\ (l) \rightarrow 2\ HCl\ (g) + Na_2O\ (s)$	ΔH = 507 kJ
$NO\ (g) + NO_2\ (g) + Na_2O\ (s) \rightarrow 2NaNO_2\ (s)$	ΔH = -427 kJ
$NO\ (g) + NO_2\ (g) \rightarrow N_2O\ (g) + O_2\ (g)$	ΔH = -43 kJ
$2HNO_2\ (l) \rightarrow N_2O\ (g) + O_2\ (g) + H_2O\ (l)$	ΔH = 34 kJ

23. Find the ΔH for the reaction below, given the following steps and subsequent ΔH values:

$Zn\ (s) + 1/8\ S_8\ (s) + 2\ O_2\ (g) \rightarrow ZnSO_4\ (s)$

$Zn\ (s) + 1/8\ S_8\ (s) \rightarrow ZnS\ (s)$	ΔH = -183.92 kJ
$2\ ZnS\ (s) + 3\ O_2\ (g) \rightarrow 2\ ZnO\ (s) + 2\ SO_2\ (g)$	ΔH = -927.54 kJ
$2\ SO_2\ (g) + O_2\ (g) \rightarrow 2\ SO_3\ (g)$	ΔH = -196.04 kJ
$ZnO\ (s) + SO_3\ (g) \rightarrow ZnSO_4\ (s)$	ΔH = -230.32 kJ

24. Calculate the $\Delta H_{formation}$ and give the overall reaction of $CS_2\ (l)$ from its elements, given the steps involved are as follows:

$C\ (s) + O_2\ (g) \rightarrow CO_2\ (g)$	ΔH = -393.5 kJ
$S\ (s) + O_2\ (g) \rightarrow SO_2\ (g)$	ΔH = -296 kJ
$CS_2\ (l) + 3\ O_2\ (g) \rightarrow CO_2\ (g) + 2\ SO_2\ (g)$	ΔH = -1072 kJ

12) flip, ÷2 $HCl_{(g)} + \frac{1}{2}Na_2O_{(s)} \rightarrow NaCl_{(s)} + \frac{1}{2}H_2O_{(l)}$ $\Delta H = \frac{-507\ kJ}{2}$

flip, ÷2 $NaNO_{2(s)} \rightarrow \frac{1}{2}NO_{(g)} + \frac{1}{2}NO_{2(g)} + \frac{1}{2}Na_2O_{(s)}$ $\Delta H = +427\ kJ/2$

÷2 $\frac{1}{2}NO_{(g)} + \frac{1}{2}NO_{2(g)} \rightarrow \frac{1}{2}N_2O_{(g)} + \frac{1}{2}O_{2(g)}$ $\Delta H = -43\ kJ/2$

Flip, ÷2 $\frac{1}{2}N_2O_{(g)} + \frac{1}{2}O_{2(g)} + \frac{1}{2}H_2O_{(l)} \rightarrow HNO_{2(l)}$ $\Delta H = -34\ kJ/2$

$HCl_{(g)} + NaNO_{2(s)} \rightarrow NaCl_{(s)} + HNO_{2(l)}$ $\Delta H_{rxn} = -78.5\ kJ$

$\frac{3}{2}O_2 + \frac{1}{2}O_2 = 2\ O_2$

23) keep $Zn_{(s)} + \frac{1}{8}S_{8(s)} \rightarrow ZnS_{(s)}$ $\Delta H = -183.92\ kJ$

÷2 $ZnS_{(s)} + \frac{3}{2}O_{2(g)} \rightarrow ZnO_{(s)} + SO_{2(g)}$ $\Delta H = \frac{-927.54}{2}\ kJ$

÷2 $SO_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow SO_{3(g)}$ $\Delta H = -196.04/2\ kJ$

keep $ZnO_{(s)} + SO_{3(g)} \rightarrow ZnSO_{4(s)}$ $\Delta H = -230.32\ kJ$

$Zn_{(s)} + \frac{1}{8}S_{8(s)} + 2\ O_{2(g)} \rightarrow ZnSO_{4(s)}$ $\Delta H = -976.03\ kJ$

24. The overall reaction of $CS_{2(\ell)}$ from its elements is the process of formation. 1 mole of compound is formed.

The Formation equation is:

$$C_{(s)} + 2\,S_{(s)} \longrightarrow CS_{2(\ell)} \qquad \text{(target equation)}$$

keep $\quad C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)} \qquad \Delta H = -393.5\,kJ$

x2 $\quad 2\,S_{(s)} + 2\,O_{2(g)} \longrightarrow 2\,SO_{2(g)} \qquad \Delta H = -296 \times 2\ kJ$

flip $\quad CO_{2(g)} + 2\,SO_{2(g)} \longrightarrow CS_{2(\ell)} + 3\,O_{2(g)} \qquad \Delta H = +1072\,kJ$

$$C_{(s)} + 2\,S_{(s)} \longrightarrow CS_{2(\ell)} \qquad \Delta H = \boxed{86.5\,kJ}$$