PQ 14 Heat

Q and A

Q1

- **How much heat is needed to raise the temperature of a block of copper (weighing 0.5 kg) from 0°C to 100° C ?** (for copper, c = 386 J / kg ^{o}C)

$$\mathbf{Q = c\,m\,\Delta T}$$

Q = 386 * 0.5 * 100 = 19300 J or 19.3 kJ

Q2

- **How much heat is needed to raise the temperature of 0.5 kg of water from 0°C to 100° C?** (for water, $c = 4186$ J / kg ^{o}C)

$$Q = 4186 * 0.5 * 100 = 209300 \text{ J or } 209.3 \text{ kJ}$$

Q3

- **What would be the final temperature of a mixture of 100 g of water at 90°C and 600 g of water at 20°C ?**

The amount of heat that will be transferred from the hotter water is:

4186 * 0.1 * (90 - Tf)

The amount of heat that will be transferred to the cooler water is:

4186 * 0.6 * (Tf -20)

Because these two quantities must be equal, we have an equation:

4186 * 0.1 * (90 - Tf) = 4186*0.6 * (Tf - 20)

We need to find Tf:

418.6 * (90-Tf) = 2511.6 * (Tf-20)

Getting rid of the brackets:

37674 - 418.6 Tf = 2511.6 Tf - 50232

-2930.2 Tf = -87906

Tf = 30° C

Q4

- **What would be the final temperature if a 2 kg piece of lead at 200°C is inserted in a container with 10 kg of water at 50°C ?** (for lead, c = 128 J / kg °C)

amount of heat transferred from the lead:

128*2*(200-Tf)

amount of heat transferred to the water:

4186*10*(Tf-50)

Equating the two heats:

128*2*(200-Tf) = 4186*10*(Tf-50)

256(200-Tf)=41860(Tf-50)

51200-256 Tf = 41860 Tf - 2093000

42116 Tf = 2144200

Tf = 50.9°

Q5

- How much heat is needed to transform 500g of ice at -20 ^oC into water at 50 ^oC ?

Q_1 = heating up the ice from -20 ^oC to 0 ^oC

Q_2 = melting the ice

Q_3 = heating up the water (molten ice) from 0 ^oC to 50 ^oC

$Q_1 = c\ m\ \Delta t = 2093*0.5*20 = 20930$ J

$Q_2 = L_f\ m = 3.33 \times 10^5 *0.5 = 170000$ J

$Q_3 = c\ m\ \Delta t = 4186*0.5*50= 104650$ J

The total heat taken is $Q_1+Q_2+Q_3 = 295580$ J = 295.58 kJ

Q6

- **a)** 4 kg of water (at 25 °C) and 2 kg of ice (at 0 °C) are mixed inside an isolated container. What is the final temperature ? Is there any ice left?
- **b)** What happens if there is only 1 kg of ice?

$L_f = 3.33 \times 10^5$ J/kg. There are 2kg so that the total heat needed is :

$Q_1 = L_f\, m = 3.33 \times 10^5 * 2 = 6.66 \times 10^5$ J.

Next, let's check how much heat is needed to bring all the water to 0 °C :

$c_{water} = 4186$ J/kg °C ,

$\Delta t = 25$, m = 4 kg, so:

$Q_2 = c\, m\, \Delta t = 4186 * 4 * 25 = 418600 \text{ J} = 4.186 \times 10^5$

Conclusion: There will be ice left, because Q_2 is lower than Q_1. The mixture will stay at 0 °C and no further heat transfers will occur (heat can only be trasferred if there is a temperature difference).

Q6 continued

- $Q_1 = L_f\, m = 3.33 \times 10^5 * 1 = 3.33 \times 10^5$ J
- In this case , $Q_1 < Q_2$ so that all the ice will be melted.
- What will be the final temperature of the mixture? We know that it will be somewhere between 0 ^oC and 25 ^oC. The molten ice is treated as 1 kg of water at 0 ^oC which is mixed with 4kg of water at 25 ^oC.
- $4186*4*(25-Tf) = Q_1 + 4186*1*(Tf-0)$
- $418600 - 16744\ Tf = 333000 + 4186\ Tf$
- $-20930\ Tf = -\ 85600$
- $Tf = 4.1\ ^oC$

Q7

- Calculate the amount of heat needed to increase the temperature of 250g of water from 20°C to 56°C.
- $q = m \times C_g \times (T_f - T_i)$
  $m = 250g$
  $C_g = 4.18\ J\ {}^oC^{-1}\ g^{-1}$ (from table above)
  $T_f = 56^oC$
  $T_i = 20^oC$
- $q = 250 \times 4.18 \times (56 - 20)$
  $q = 250 \times 4.18 \times 36$
  $q = 37\ 620\ J = 38\ kJ$

Q8

- Calculate the specific heat capacity of copper given that 204.75 J of energy raises the temperature of 15g of copper from 25^o to 60^o.
- $q = m \times C_g \times (T_f - T_i)$
  q = 204.75 J
  m = 15g
  $T_i = 25^oC$
  $T_f = 60^oC$
- $204.75 = 15 \times C_g \times (60 - 25)$
  $204.75 = 15 \times C_g \times 35$
  $204.75 = 525 \times C_g$
  $C_g = 204.75 \div 525 = 0.39\ J^oC^{-1}\ g^{-1}$

Q9

- 216 J of energy is required to raise the temperature of aluminium from 15^o to 35^{o}C. Calculate the mass of aluminium.
(Specific Heat Capacity of aluminium is 0.90 J^{o}C^{-1}g^{-1}).

- $q = m \times C_g \times (T_f - T_i)$
$q = 216$ J
$C_g = 0.90$ J^{o}C^{-1}g^{-1}
$T_i = 15^oC$
$T_f = 35^oC$
- $216 = m \times 0.90 \times (35 - 15)$
$216 = m \times 0.90 \times 20$
$216 = m \times 18$
$m = 216 \div 18 = 12g$

Q10

- The initial temperature of 150g of ethanol was 22^oC. What will be the final temperature of the ethanol if 3240 J was needed to raise the temperature of the ethanol?
(Specific heat capacity of ethanol is 2.44 $J^oC^{-1}g^{-1}$).

- $q = m \times C_g \times (T_f - T_i)$
$q = 3240$ J
$m = 150g$
$C_g = 2.44\ J^oC^{-1}g^{-1}$
$T_i = 22^oC$
- $3240 = 150 \times 2.44 \times (T_f - 22)$
$3240 = 366\ (T_f - 22)$
$8.85 = T_f - 22$
$T_f = 30.9^oC$

Q11

- How much water at 50°C is needed to just melt 2.2 kg of ice at 0°C?

$$Heat\ loss = heat\ gain$$
$$Heat\ loss\ of\ water = heat\ to\ melt\ ice$$
$$m_{water} c_{water} \Delta T = m_{ice} L_f$$
$$m_{water} * 4200 * (50 - 0) = 2.2 * 3.34 * 10^5$$
$$m_{water} = 3.50\ kg$$

Q12

- How much water at 32°C is needed to just melt 1.5 kg of ice at -10°C?

$$Heat\ loss = heat\ gain$$

$$Heat\ loss\ of\ water = heat\ gain\ of\ ice + heat\ to\ melt\ ice$$

$$m_{water} c_{water} \Delta T = m_{ice} c_{ice} \Delta T + m_{ice} L_f$$

$$m_{water} * 4200 * (32 - 0) = 1.5 * 2300 * (0 - (-10)) + 1.5 * 3.34 * 10^5$$

$$m_{water} = 3.98\ kg$$

Q13

- How much steam at 100° is needed to just melt 5 kg of ice at -15°C?

$Heat\ loss = heat\ gain$

$Heat\ to\ condense\ steam + Heat\ loss\ of\ water = heat\ gain\ of\ ice + heat\ to\ melt\ ice$

$m_{steam}L_v + m_{steam}c_{water}\Delta T = m_{ice}c_{ice}\Delta T + m_{ice}L_f$

$m_{steam} * 22.5 * 10^5 + m_{steam} * 4200 * (100 - 0) = 5 * 2300 * (0 - (-15)) + 5 * 3.34 * 10^5$

$2.67 * 10^6 * m_{steam} = 1.84 * 10^6$

$m_{steam} = 0.69\ kg$

Q14

- A copper cup holds some cold water at 4°C. The copper cup weighs 140g while the water weighs 80g. If 100g of hot water, at 90°C is added, what will be the final temperature of the water?

$$Heat\ loss = heat\ gain$$
$$heat\ gain\ of\ cup + heat\ gain\ of\ cold\ water = heat\ loss\ of\ hot\ water$$
$$m_{cup}c_{cup}\Delta T + m_{cw}c_w\Delta T = m_{hw}c_w\Delta T$$
$$0.14 * 390 * (T_F - 4) + 0.08 * 4200 * (T_F - 4) = 0.1 * 4200 * (90 - T_F)$$
$$390.6T_F - 1562.4 = 37800 - 420T_F$$
$$810.6T_F = 39362.4$$
$$T_F = 48.6°C$$

Q15

- A kettle uses 160kJ of energy to heat the water in it from 25°C to 100°C.
- How much water is in the kettle in kg?

- Mass = 160,000/(4200 x 75)   = 0.51kg or 510g

Q16

- A chemist uses a Bunsen burner to heat some ethanol in a beaker. If the energy input is 2.5kJ and the temperature change is 21°C to 32°C, find the mass of ethanol that was heated in kg.

- Mass = 2500/(2400 X 11) = 0.095kg

Q17

- A spinning bicycle wheel needs to be brought to a stop by a rubber brake block. Assuming the wheel has 500J of kinetic energy that is all absorbed by the brake and that the mass of the block is 25g, how much will the temperature of the block rise by in °C?

- $\Delta°C = 500/(0.025 \times 2000) = 10\ °C$

Q18

- A convection heater is used to heat the air in a house. If it is on for 15 minutes and transfers 2000kJ of heat energy to the air, find the increase in temperature of the air in °C if there is 124kg of air in the room.

- $\Delta°C = 2{,}000{,}000/(124 \times 1000) = 16.1\ °C$

Q19

- An electrical circuit malfunctions and starts to overheat. The copper wire of the circuit has a mass of 3g and it increases in temperature from 20°C to 60°C.
- How much energy is transferred to the wire in joules?

- $E = 0.003 \times 390 \times 40 = 46.8$ J

Q20

An alloy of unknown composition is heated to 137 °C and placed into 100.0 g of water at 25.0 °C. If the final temperature of the water was 36.4 °C, and the alloy weighed 2.71 g, what is the specific heat capacity of the alloy? The specific heat of water is 4.184 J/g°C.

The system is the alloy, and the surroundings are water.

ΔT_{sys} = 36.4 °C – 137 °C = -101 °C ΔT_{surr} = 36.4 °C – 25.0 °C = 11.4 °C

$$(2.71g)c_{sys}(-101°C) + (100.0g)\left(4.184\frac{J}{g°C}\right)(11.4°C) = 0$$

$$-274g°C \cdot c_{sys} + 4770J = 0 \qquad c_{sys} = \frac{-4770J}{-274g°C} = 17.4\frac{J}{g°C}$$