Conservation of Mass

1. It has been observed that 14.0 g of nitrogen will combine with 3.0 g of hydrogen to produce ammonia (NH_3).

a) How much ammonia is produced when 100.0 g of nitrogen gas is reacted with 50.0 g of hydrogen gas?

Ans. In this problem, hydrogen is the limiting reactant and will be completely reacted before the nitrogen is used up (there will be excess nitrogen). According to the Law of Conservation of Mass: 14.0 g of N_2 + 3.0 g of H_2 = 17.0 g total mass (or mass of NH_3), therefore there is a 3.0:17.0 gram mass ratio of H_2 to NH_3

$$(50.0\text{ g H}_2)\left(\frac{17.0\text{ g NH}_3}{3.0\text{ g H}_2}\right) = 2.8\text{x}10^2\text{g NH}_3$$

Note that neither the 3.0g nor the 14.0 g are exact numbers, they themselves are measurements with significant figures.

b) How much ammonia is produced when 10 grams of nitrogen gas is reacted with 10 grams of hydrogen gas?

Ans. The amount of hydrogen that is reacted in this reaction is:

$$(10\text{ g N}_2)\left(\frac{3.0\text{ g H}_2}{14.0\text{ g N}_2}\right) = 2\text{ g H}_2$$

According to the Law of Conservation of Mass, the mass of ammonia produced is the combination of hydrogen and nitrogen reacted or

$$2.1\text{g} + 10.0\text{g} = 12.1\text{g of NH}_3$$

c) If 25.0 grams of hydrogen gas are completely reacted, how much nitrogen is needed?

Ans. The amount of nitrogen that is reacted is:

$$(25.0\text{ g H}_2)\left(\frac{14.0\text{ g N}_2}{3.0\text{ g H}_2}\right) = 1.2\text{x}10^2\text{g N}_2$$

d) How much ammonia is produced?

Ans. According to the Law of Conservation of Mass, the mass of ammonia produced is the combination of hydrogen and nitrogen reacted or

$$25.0\text{ g} + 1.2\text{x}10^2\text{g} = 12.1\text{g of NH}_3$$

2) Elemental tin and chlorine gas combine in a mass ratio of 11.0 g Sn to 10.0 g Cl_2 to produce tin(III) chloride ($SnCl_3$).

a) How much tin is needed to completely react 25 grams of chlorine gas?

Ans. $(25.0\text{ g Cl}_2)\left(\frac{11.0\text{ g Sn}}{10.0\text{ g Cl}_2}\right) = 27.5\text{g Sn}$

b) How much tin(III) chloride is produced?

Ans. According to the Law of Conservation of Mass, the mass of tin(III) chloride produced is the combination of tin and chlorine reacted, or

25.0 g + 27.5 g = 52.5g of $SnCl_3$

c) How much tin(III) chloride is produced when 100 grams of tin is reacted with 50 grams of chlorine gas?

Ans. In this problem, chlorine is the limiting reactant and will be completely reacted before the tin is used up (there will be excess tin). According to the Law of Conservation of Mass: 11.0 g of Sn + 10.0 g of Cl_2 = 21.0 g total mass (or mass of $SnCl_3$), therefore there is a 10.0:21.0 gram mass ratio of Cl_2 to $SnCl_3$

$$(50\text{ g }Cl_2)\left(\frac{21.0\text{ g }SnCl_3}{10.0\text{ g }Cl_2}\right) = 100\text{ g }SnCl_3\ (1\text{ sig fig})$$

d) How much tin(III) chloride is produced when 10 grams of tin is reacted with 10 grams of chlorine gas?

Ans. In this problem, tin is the limiting reactant and will be completely reacted before the chlorine is used up (there will be excess chlorine). The gram mass ratio is 11.0:21.0 for Sn to $SnCl_3$

$$(10\text{ g Sn})\left(\frac{21.0\text{ g }SnCl_3}{11.0\text{ g Sn}}\right) = 20\text{ g }SnCl_3\ (1\text{ sig fig})$$

Heat & Specific Heat Capacity:

3. A metal object of mass = 20.00 g is heated from a temperature of 25.0 ^oC to 200.0 ^oC. During this process, the metal object absorbs 1.34×10^3 J of energy.

(i) What is the specific heat capacity?

Ans. s = 0.383 J/g^{o}C

(ii) What is the heat energy required to raise the temperature of the metal object in calories?

Ans. s = 320. cal

4. The hot metal object (in problem 1 above) is then placed into a thermally isolated container with 20.00 g of water, initially at 25.0 ^oC.

(i) What happens to the temperature of the water? The metal object?

Ans. The water warms up, increases temperature.

The metal object cools down, decreases temperature.

(ii) Describe the flow of energy (heat) inside the container.

Ans. Heat energy flows from the metal object into the water.

(iii) What is the final temperature of the water/metal object?

Ans. Both the metal and water reach the same final temperature at thermal equilibrium, and the heat lost by the metal is equal to the heat gained by the water, therefore:

$Q_{Water} = -Q_{Metal}$ or $(s \cdot m \cdot \Delta T)_{Water} = -(s \cdot m \cdot \Delta T)_{Metal}$

Solving for T and inserting all of the numerical values $\rightarrow$ T = 40. ^oC

5. In a separate experiment, an identical metal object at a temperature of 100.0 ^oC is placed into a thermally isolated container containing 50.00 kg of a liquid (initial

temperature of 20.0 °C) with an unknown specific heat capacity. The final temperature of the mystery liquid/metal object is 23.5 °C.

(i) What is the specific heat capacity of the mystery liquid?

Ans. The heat lost by the metal is equal to the heat gained by the liquid, therefore:

$Q_{liquid} = -Q_{Metal}$ or $(s \cdot m \cdot \Delta T)_{liquid} = -(s \cdot m \cdot \Delta T)_{Metal}$

Solving for s_{liquid} and inserting all of the numerical values $\rightarrow s_{liquid} = 3.3$ J/g°C

(ii) How much heat (in Joules) would be needed to raise the temperature of the unknown liquid from 25.0 °C to 100.0 °C?

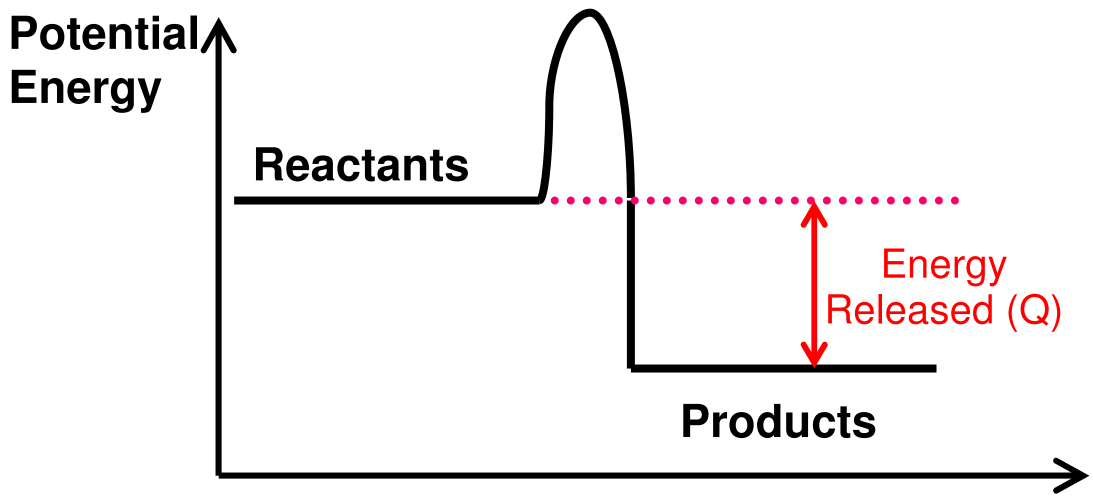
Ans. $Q = s_{liquid} \cdot m_{liquid} \cdot \Delta T_{liquid} = 1.2 \times 10^4$ J

(ii) How much heat (in calories) would be needed to raise the temperature of the unknown liquid from 25.0 °C to 100.0 °C?

Ans. $Q = 2.9 \times 10^3$ cal

Heat & Specific Heat Capacity:

6. Sketch a simple potential energy diagram for an exothermic reaction?



7. Sketch a simple potential energy diagram for an endothermic reaction?