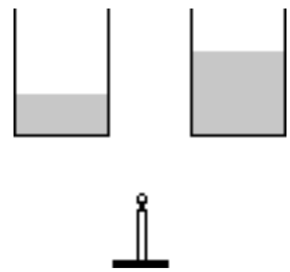
During Class Invention

Mass, temperature and heat

Name(s) with Lab section in Group

1. Two containers of water are at 20 ˚C initially. One contains 50 mLs and the other 100 mLs. They are each heated with the same source of heat for the same amount of time. If the final temperature of the 50 mLs sample is 50 ˚C what would be the final temperature of the 100 mLs sample?



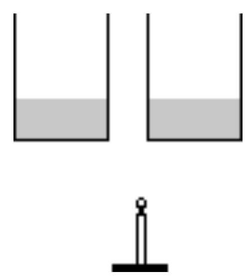
A. 50 ˚C
B. 80 ˚C
C. 25 ˚C
D. 100 ˚C
E. 35 ˚C

Explain:

The two beakers each receive the same amount of heat, but the mass of one beaker is half the other. Since the ΔT for the beaker with the smaller amount is 30 ˚C, the other beaker with twice the amount will undergo half the change in temperature. So ΔT will be 15 ˚C, and the final temperature will be 35 ˚C.

$$\textbf{Mass}\ \alpha\ \frac{1}{\Delta T}$$

2. Two containers each have 50 mLs of water at 20 ˚C initially. They are each heated with the same source of heat. One is heated for ten minutes and the other for five minutes. If the container that was heated for five minutes has a final temperature 30 ˚C what would be the final temperature of the other sample?



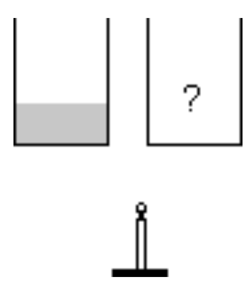
A. 35 ˚C
B. 40 ˚C
C. 60 ˚C
D. 25 ˚C
E. 30 ˚C

Explain:

The two beakers have the same amount of water but one beaker is heated twice as long (twice the amount of heat transferred). If the ΔT for the beaker receiving the smaller amount of heat is 10 ˚C, then the ΔT for the beaker receiving twice the heat will be twice the ΔT, or 20 ˚C. SO the final temperature will be 40 ˚C.

$$\textbf{q(heat)}\ \alpha\ \Delta T$$

3. Two containers of water are at 20 ˚C initially. One contains 50 g of water and is heated by a source for a specified time to a final temperature of 30 ˚C. The second container has an unknown amount of water and is heated with the same source to 30 ˚C. However, it takes twice as long to get to this final temperature. How much water is in this container?



A. 100 g
B. 25 g
C. 30 g
D. 50 g
E. 75 g

Explain:

In this example twice the amount of heat is added to one of the beakers to reach the same final temperature (the same ΔT). For this to happen that beaker must have twice the mass, or 100 g.

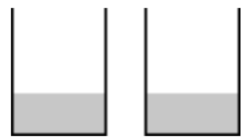
$$\textbf{q(heat)} \ \alpha \ \textbf{mass}$$

After these three experiments we can relate the three proportionalities that we have produced into the following relationship;

$$\textbf{q(heat)} \ \alpha \ \textbf{mass} \cdot \Delta \textbf{T}$$

Each of the three proportionalities can be generated from this proportionality. So let's try to apply this relationship in the following three problems.

4. 50 mLs of water at 80 ˚C is added to 50 mLs of water at 20 ˚C. What would be the final temperature?



A. 60 ˚C
B. 40 ˚C
C. 30 ˚C
D. 20 ˚C
E. 50 ˚C

Explain:

In this experiment we need to remember the first law of thermodynamics, that heat can not be created or destroyed. Interpreting the first law of thermodynamics for this situation means that the heat given off by the hot water must equal the heat gained by the cold water. We can express this mathematically as,

$$q_{\text{hot } H_2O} = -\, q_{\text{cold } H_2O}$$

We established in DCI15.1 – 16.3 that

$$\textbf{q(heat)} \ \alpha \ \textbf{mass} \cdot \Delta \textbf{T}$$

So we can substitute

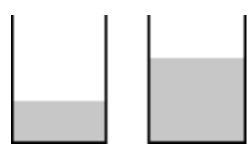
$$(m \cdot \Delta T)_{\text{hot } H_2O} = -(m \cdot \Delta T)_{\text{cold } H_2O}$$

$$50\text{ g} \cdot (T_f - 80.0\ ˚C) = -(50.0\text{ g} \cdot (T_f - 20.0\ ˚C))$$

$$2T_f = 100.0\ ˚C$$

$$T_f = 50.0\ ˚C$$

5. 50 mLs of water at 80 ˚C is added to 100 mLs of water at 20 ˚C. What would be the final temperature?



A. 70 ˚C
B. 40 ˚C
C. 30 ˚C
D. 60 ˚C
E. 50 ˚C

Explain:

$$q_{\text{hot } H_2O} = -q_{\text{cold } H_2O}$$

We established in DCI15.1 – 16.3 that

$$q(\text{heat}) \propto \text{mass} \cdot \Delta T$$

So we can substitute

$$(m \cdot \Delta T)_{\text{hot } H_2O} = -(m \cdot \Delta T)_{\text{cold } H_2O}$$

$$50\text{ g} \cdot (T_f - 80.0\ ^\circ C) = -(100.0\text{ g} \cdot (T_f - 20.0))$$

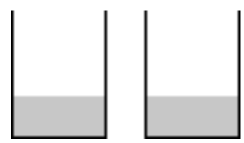
$$T_f - 80.0\ ^\circ C = -(2(T_f - 20.0\ ^\circ C))$$

$$T_f - 80.0\ ^\circ C = -2T_f + 40.0\ ^\circ C))$$

$$3T_f = 120.0\ ^\circ C$$

$$T_f = 40.0\ ^\circ C$$

6. 50 g of water at 80 ˚C is added to 50 g of ethyl alcohol at 20 ˚C. What would be the approximate final temperature?



A. 60 ˚C
B. 40 ˚C
C. 30 ˚C
D. 20 ˚C
E. 50 ˚C

Explain:

Here we have an issue that has not arisen in the previous problems. That of mixing two different substances. This presents us with the issue of whether the two substance have some property that might result in a final temperature different than what we calculated in DCI15.4. While we might think the final temperature in this problem is the same as DCI15.4, or 50 ˚C, the final temperature is in fact closer to 60 ˚C. How could that be?

It turns out the proportionality that we developed in DCI15.1 – 16.3

$$q(\text{heat}) \propto \text{mass} \cdot \Delta T$$

can be converted to an equality by introducing a constant. The constant is called the specific heat (S.H.) and is a property of a pure substance. So the equation is change to an equality and is,

$$q(\text{heat}) = \text{mass} \cdot \text{S.H.} \cdot \Delta T$$

Specific heat has the units $\frac{J}{g \cdot ^\circ C}$. For liquid water the specific heat is 4.184 $\frac{J}{g \cdot ^\circ C}$, while for ethyl alcohol the specific heat is 2.3 $\frac{J}{g \cdot ^\circ C}$. So lets consider the last problem using this new form of the heat equation,

$$q_{\text{lost by hot } H_2O} = -\, q_{\text{gained by the cold ethyl alcohol}}$$

$$q = m \cdot s.h. \cdot \Delta T$$

$$(m \cdot s.h. \cdot \Delta T)_{H_2O} = -(m \cdot s.h. \cdot \Delta T)_{\text{ethyl alcohol}}$$

$$(50.0\ g \cdot \left(4.184\ \frac{J}{g \cdot °C}\right) \cdot (T_f - 80.0\ °C)) = -(50.0\ g \cdot \left(2.3\ \frac{J}{g \cdot °C}\right) \cdot (T_f - 20.0\ °C))$$

$$209.2\ \frac{J}{°C} \cdot (T_f - 80.0\ °C) = -(115\ \frac{J}{°C} \cdot (T_f - 20.0\ °C))$$

$$1.82 \cdot (T_f - 80.0\ °C) = -(T_f - 20.0\ °C)$$

$$1.82T_f - 145.6\ °C = -(T_f - 20.0\ °C)$$

$$2.82T_f = 165.6\ °C)$$

$$T_f = 58.7\ °C$$