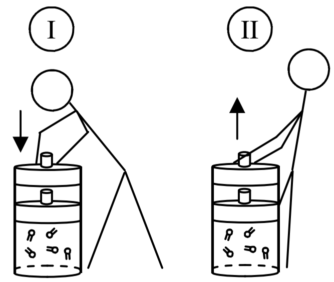
Heat and Thermo 5



Slim Jim is pushing or pulling on the piston as shown. The arrows show the direction the piston moves. Things to remember: 1) when a gas is compressed its molecules speed up due to the collision with the piston, raising its temperature and internal energy, like a bat hitting a bat; 2) the "system" is the gas molecules inside the piston; 3) the piston's normal force always pushes down (that's what makes the gas molecules go down after they hit the piston); 4) the gas molecules always push up on the piston (that's what keeps the piston from falling, otherwise known as "gas pressure").

1. Which diagram above shows the following?

A. ______ The gas increasing in temperature.
B. ______ Positive work done on the gas.
C. ______ Negative work done by the gas.
D. ______ Gas losing internal energy.
E. ______ Negative work done on the gas.
F. ______ Positive work done by the system.
G. ______ The system gaining internal energy.
H. ______ The piston losing potential energy.
I. ______ The gas molecules gaining kinetic energy.

1. A: I
B: I C: I
G: I
H. I
I. I

The First Law of Thermodynamics says a gas can increase its internal energy (U) from either heat or work (change of pressure). It is written as $\Delta U = Q + W_{on\ the\ gas}$ OR $\Delta U = Q - W_{by\ the\ gas}$. Let me show you why these are equivalent.

2. A sample of gas absorbs 200 J of heat while 60 J of work is done on the gas, compressing the cylinder.
A. What is Q? B. What is $W_{on\ the\ gas}$? C. What is ΔU?

2A: +200J (added)
2B: +60J
2C: 200 + 60 = +260J

3. There is 200J of heat exchanged in an endothermal process for a gas. The gas does −60 J of work.
A. What is Q? B. What is $W_{by\ the\ gas?}$ C. What is ΔU?

3A: +200J (endo=Qin)
3B: −60J
3C: 200−(−60) = 260J

So, it doesn't matter if the work is on or by the gas, only that the gas was compressed.

4. 400 J of heat is removed from a gas while 250 J of work is done on the system. Calculate the change of internal energy.

4. −400 + 250 = −150 J

5. 300 J of work is done by the system while 1200 J of heat is added to the system. What is the total change of internal energy of the gas?

Work Done by a Gas

Work (*in J*) → $W = P\Delta V$ ← Change in Volume (*in* m^3)

Pressure (*in Pascals or* N/m^3)

But we generally talk about the pressure and volume of a gas, instead of force and distance. I expect that you know how to find the volume of a cylinder: $\pi r^2 h$; or a rectangular solid: l(w)h.

Also, even though we know that the pressure of the gas does increase as the piston compresses, this is too hard to calculate, so we pretend that the pressure is constant (isobaric).

6. *A piston has a radius of 6 cm. It moves down 12 cm under a pressure of 3 atmospheres (3.03×10^5 Pa).
A. Calculate the area of the circular piston.

B. Calculate the change of volume of the piston.

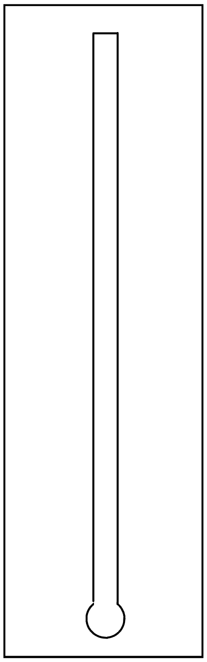
C. Calculate the work done by the gas.

Specific heat	Liquid	Solid
aluminum	1180	899

Latent Heat	L_{fusion}	$L_{vaporization}$
aluminum	3.97×10^5	1.14×10^7
Boiling point	2494°C	
Freezing point	660°C	

You can calculate total heat for substances other than water.
Let me walk you thru it.

7. 4 kg of aluminum is at 80°C. How much heat is necessary to raise it to 750°C?



A. Label the boiling point and freezing point of aluminum on the thermometer.

B. Mark the first and final temperature on the thermometer. Don't worry about an exact position. Just make sure they are in the correct phase.

C. The aluminum starts as what phase?

D. The aluminum ends as what phase?

E. Remember that $Q = mc_p\Delta T$ and that $\Delta T = T_{final} - T_{initial}$, calculate amount of heat necessary to raise the aluminum to its melting point.

Now that aluminum is at 660°C (its melting point), it needs to be melted.

F. Will you use the latent heat of fusion or vaporization to melt the aluminum?

G. Calculate the heat necessary to melt the aluminum.

H. What is the starting temperature of the liquid aluminum?

I. Now, calculate the heat necessary to raise the aluminum from its melting point to 750°C.

J. Calculate the total heat necessary to raise the aluminum from 80°C to 750°C.

A. See above.

B. Ti = 80°C
Tf = 750°C

C. Solid
(below 660°C)

D. Liquid

E. Q = (4)(899)
(660–80)
= 2.09E6J

F. Fusion: melting is "unfusing"

G. Q = mL fusion
$= 4(3.97 \times 10^5)$
= 1.59E6J

H. 660°C

I. Q = 4(1180)
(750–660)
= 4.25E5J

J. Add em up:
2.09E6J
+ 1.59E6J
+ 4.25E5J
= 4.11E6J

1C: + 1D: 50 J 1E: 5 m/s 2C: – 2E: 0 m/s 3B: +
4: – 5: increase 6A: – 6B: – 6C: + 7A: $A = \pi r^2 = 0.0113\ m^2$ (r = 0.06 m)
7B: $\Delta V = -1.36E{-3}\ m^3$ 7C: W = –411 J