1. D The conversion from the celcius to the Fahrenheit scale is as follows:

$$T_f = \tfrac{9}{5}T_c + 32$$

Here is the conversion from celcius to Kelvin (Kelvin, being the *true thermodynamic temperature*, gets the plain symbol T):

$$T = T_C + 273.15$$

2. C The *heat capacity* is the quantity of heat required to raise the temperature of a *body* (a stone, the chair, etc.) one degree Kelvin. The *specific heat capacity* is the quantity required to raise the temperature of *one gram of a substance* one degree Kelvin. The molar heat capacity is the same for *one mole of a substance.*

3. A The strings, having a greater coefficient of linear expansion than the neck of the quitar, will expand more at the higher temperature than the neck. Thus they will lose a bit of tension, sounding slightly flat.

4. A The first thing that occurs upon heating is the expansion of the metal bulb, causing the mercury to drop at first.

5. B One mole of an ideal gas at *STP* occupies 22.4 liters (answer A). However, att room temperature, approximately 298 K, one mole of an ideal gas occupies 24.4 liters.

6.* C The necessary heat equals the amount energy required to bring the water to 0 ^oC (The specific heat capacity of ice is .50 cal/g ^oC (or K), at which the point the *heat of fusion* must be added, which *does not* raise the temperature. Then we must bring the water from 0 ^oC to 100 ^oC (1 cal/g ^oC), after which we allow the *heat of vaporization* to flow into the system.

$$Q_{-50°C \to 0°C} = (100\ g)\ (.50\ \frac{cal}{g\ °K})\ (50\ K) = 2500\ cal$$
$$Q_{fusion} = (100\ g)\ (80\ \frac{cal}{g\ °K}) = 8000\ cal$$
$$Q_{0°C \to 100°C} = (100\ g)\ (1\ \frac{cal}{g\ °K})\ (100\ K) = 10000\ cal$$
$$Q_{vaporization} = (100\ g)\ (540\ \frac{cal}{g\ °K}) = \underline{54000}\ cal$$
$$sum = 74500\ cal$$

7. A Heat flow through a body is proportional to the temperature difference across the body:

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x}$$

8. D The rate of heat radiation by a body is proportional to the *fourth* power of the temperature:

$$P = \sigma\ A\varepsilon T^4$$

9. D Picture a membrane separating a gas within a canister from an area of vacuum. When the membrane is broken, the gas will undergo an adiabatic free expansion. The expansion will require no work and involve no heat flow. However, the entropy of the gas will increase. If you don't understand why, try to reverse the process.

10.* D All three are possible Carnot cycles. Choice B represents the most familiar version, in which heat flows from the hot to the cold sink. The other two are the Carnot cycle in reverse (the action of a heat pump or refrigerator) in which we move the heat from the cold to the hot sink.

11. B That the Carnot cycle is reversible, is another way of saying that its action does not increase the entropy of the universe.

12. A The maximum efficiency (Carnot efficiency) is given by: (use Kelvin!)

$$\varepsilon = \frac{W}{Q_h} = 1 - \frac{Q_c}{Q_h} = 1 - \frac{T_c}{T_h}$$

13.* D To find how many grams we have, first we must compute the number of moles of gas present in a system defined by given values of the state functions of our gas (P, V, T), using the ideal gas law (the equation of state of an ideal gas):

$$PV = nRT$$

$$(80\ atm)\ (30.3\ L) = n\ (.08\ \frac{L\ atm}{mol\ K})\ (303\ K)$$
$$n = 100\ mol$$
$$(100\ mol)\ (16\ \frac{g}{mol}) = 1.6 \times 10^3\ g$$

14. C This is one of those MCAT questions where none of the answers is perfect. We're then left with choosing the *best* answer. We know that A and B are both obviously incorrect because heat will definately be flowing from the tires into the snow until thermal equilibrium is achieved. Pressure does definately go down with decreasing internal energy at constant volume. However, the weight of the car combined with the elasticity of the tires will ameliorate this effect somewhat by decreasing the volume.

15. C The entropy change of heat flow into an object at constant temperature will satisfactorily approximates the situation:

$$\Delta S = \frac{\Delta Q_r}{T}$$

The object into which heat flows receives a positive entropy change.
The snow is at a lower temperature than the tire. This results in its positive entropy change being of greater magnitude (absolute value) than the negative entropy change of the tire. This fact corresponds to the entropy of the universe increasing, and thus the irreversibility of the process, when heat flows from the higher temperature to the lower temperature body.

16.* B Remeber the molar heat capacity of an ideal gas:

$$C_v = \tfrac{3}{2}R$$

Converting our mass to moles, then employing a form of the above with calories as our units, we can compute the heat flow from the tires due to the temperature drop:

$$(100\ \text{mol})\ \left(3\ \frac{\text{cal}}{\text{mol}\ {}^\circ\text{K}}\right)\ (30\ {}^\circ\text{K}) = 9000\ \text{cal}$$

Don't forget, however, that volume is decreasing. This means that the environment will be performing work on our system, adding energy to the tires. This energy, as heat, must also eventually flow out as temperature falls in the tires. At constant pressure, we know by Charles' law that, when the temperature (°K) decreases by 10%, so also does the volume. The original volume was about 30 L, so it decreases by 3 L (3 X 10^{-3} m^3):

$$P\Delta V = (3 \times 10^{-3}\ \text{m}^3)\ (8 \times 10^5\ \text{Pa}) = 24000\ \text{J} = 6000\ \text{cal}$$

Because the external temperature is above freezing, we can assume that the snow is at 0 °K. Therefore, only the heat of fusion is required to bring about melting:

$$15000\ \text{cal} \times \frac{1\ \text{g}}{540\ \text{cal}} \approx 25\ \text{g}$$

17. C If each stage of a process is an equilibrium state (as in the Carnot cycle) then the universe gains no entropy thereby, and the transformation is reversible. This is definately not the case here. Without the addition of energy, all spontaneous processes are irreversible.

18. B When we run a Carnot cycle backwards, what we are basically doing is pulling heat from the cold sink through isothermal expansion, and then expelling the heat through isothermal compression on the hot sink. There is more heat expelled by an amount of added work. The ratio of the amount of heat expelled to the work we put in is called the coefficient of performance of the heat pump:

$$\text{COP} = \frac{Q_h}{W} = \frac{T_h}{T_h - T_c}$$

19. B Temperature is constant in boiling water. The entropy change to the water as heat flows in is given by:

$$\Delta S = \frac{\Delta Q_r}{T}$$