Please show all work for partial credit

1. Energy of blowing up an air mattress. At home I have a queen size air mattress. When it is folded up, it measures 16 in x 16 in x 3 in. When it is blown up it measures 78 in x 57in x 8 in.

   A. (4 points) How much work is performed when I blow the mattress up (Against 1 atm of pressure)?

   \[ V_f = 78 \text{in} \times 57 \text{in} \times 8 \text{in} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{1 \text{ml}}{1 \text{cm}^3} \times \frac{1 \text{l}}{1000 \text{ml}} \]

   \[ = 582.9 \text{l} \]

   \[ V_i = 16 \text{in} \times 16 \text{in} \times 3 \text{in} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{2.54 \text{cm}}{\text{in}} \times \frac{1 \text{ml}}{1 \text{cm}^3} \times \frac{1 \text{l}}{1000 \text{ml}} \]

   \[ = 12.6 \text{l} \]

   \[ \Delta V = V_f - V_i = 582.9 - 12.6 = 570.3 \text{l} \]

   \[ w = -P\Delta V = -1 \text{atm} \times 570.3 \text{l} = -570.3 \text{l} \cdot \text{atm} \]

   \[ -570.3 \text{l} \cdot \text{atm} \times 101.3 \text{J} / \text{l} \cdot \text{atm} = -57770 \text{J} = -57.8 \text{kJ} \]

   B. (4 points) The process of blowing up the mattress makes the air in the mattress a bit warmer. If the air is at 22°C when I start filling the mattress, and it warms to 30°C at the end of the filling process, what how much heat was evolved in the process? (Assume the air in the mattress has a density of 1.205 g/liter, and a heat capacity of a 1.005 J/g°C)

   \[ q = s. \text{H.C.} \times \Delta T \times g \]

   \[ s. \text{H.C.} = 1.005 \text{J} / \text{g} \cdot ^\circ \text{C} \]

   \[ \Delta T = 30 - 22 = 8^\circ \text{C} \]

   \[ g = \text{volume} \times \text{density} = 570.3 \text{l} \times 1.205 \text{g} / \text{l} = 687.2 \text{g} \]

   \[ q = 1.005 \times 8 \times 687.2 = 5530 \text{J} = 5.5 \text{kJ} \]

   C. (4 points) What is the ΔE for the overall process of blowing up the mattress?

   \[ \Delta E = q + w = -57.8 \text{kJ} + 5.5 \text{kJ} = -52.3 \text{kJ} \]
2. (12 points) Dedicated to Mrs. Z. and her horses. An iron horseshoe weighs 320g. In the process of making a horseshoe, the shoe is heated until it is glowing red, it is then pounded into shape and plunged into an 8 liter (2 gallon) bucket of water to cool it off. If the temperature in the bucket changes from 25°C to 27.5°C, what was the temperature of the horseshoe before it was put into the bucket? (Specific heat capacity of Iron is .45 J/°C·g, the specific heat capacity of water is 4.18 J/°C·g)

\[
1\text{ml water} = 1\text{g} \implies 8\text{l water} = 8,000\text{g water}
\]

Heat lost by horseshoe = Heat gained by water

\[
\text{Heat lost by horseshoe} = \text{S. H. C.} \times g \times \Delta T = 0.45\, \text{J/°C} \times 320\, \text{g} \times (T - 27.5)
\]

\[
\text{Heat gained by water} = \text{S. H. C.} \times g \times \Delta T = 4.18\, \text{J/°C} \times 8000\, \text{g} \times (27.5 - 25)
\]

\[
0.45\, \text{J/°C} \times 320\, \text{g} \times (T - 27.5) = 4.18\, \text{J/°C} \times 8000\, \text{g} \times (27.5 - 25)
\]

\[
144(T - 27.5) = 83,600J
\]

\[
T - 27.5 = \frac{83,600}{144} = 580.6
\]

\[
T = 580.6 + 27.5 = 608.1°C
\]

3. (12 points) A Hess’s law problem for biologists!

One way your body gets energy is from the oxidation of glucose:

\[
\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g}) \quad \Delta H_{\text{rxn}} = -2,840 \, \text{kJ/mol}
\]

Another reaction the body uses to get energy is the hydrolysis of ATP:

\[
\text{ATP} \rightarrow \text{ADP} + \text{P}_i \quad \Delta H_{\text{rxn}} = -30.5 \, \text{kJ/mol}
\]

Where does the ATP come from? It comes from your body using the energy of the Glucose oxidation to make the ATP. The net reaction here is:

\[
\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) + 6\text{O}_2(\text{g}) + 30 \ \text{ADP} + 30 \ \text{Pi} \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g}) + 30 \ \text{ATP}
\]

Calculate the net \(\Delta H\) for this last reaction, given the \(\Delta H\)'s of the other two reactions.

\[
\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) + 6\text{O}_2(\text{g}) \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g}) \quad \Delta H_{\text{rxn}} = -2,840 \, \text{kJ/mol}
\]

(Reaction goes forward so use as is)

\[
\text{ATP} \rightarrow \text{ADP} + \text{P}_i \quad \Delta H_{\text{rxn}} = -30.5 \, \text{kJ/mol}
\]

(Need to reverse reaction and multiply by 30)

\[
\text{ADP} + \text{P}_i \rightarrow \text{ATP} \quad \Delta H_{\text{rxn}} = (+30.5)\times30 \, \text{kJ/mol}
\]

Net:

\[
\text{C}_6\text{H}_{12}\text{O}_6 (\text{aq}) + 6\text{O}_2(\text{g}) + 30 \ \text{ADP} + 30 \ \text{Pi} \rightarrow 6\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g}) + 30 \ \text{ATP}
\]

\[
\Delta H_{\text{rxn}} = -2,840 \, \text{kJ/mol} + (30.5\times30) = -1,925 \, \text{kJ/mol}
\]
4. (12 points) Calculate $\Delta H$ for the reaction:

$$\text{Ca}_3(\text{PO}_4)_2(\text{s}) + 3\text{H}_2\text{SO}_4(\text{l}) \rightarrow 3\text{CaSO}_4(\text{s}) + 2\text{H}_3\text{PO}_4(\text{l})$$

Using the some of the $\Delta H_i$ values found in the table below.

<table>
<thead>
<tr>
<th>Compound</th>
<th>$\Delta H_i$(kJ/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Ca}_3(\text{PO}_4)_2$(s)</td>
<td>-4126</td>
</tr>
<tr>
<td>$\text{H}_2\text{SO}_4$(l)</td>
<td>-814</td>
</tr>
<tr>
<td>$\text{H}_2\text{SO}_4$(aq)</td>
<td>-909</td>
</tr>
<tr>
<td>$\text{CaSO}_4$(s)</td>
<td>-1433</td>
</tr>
<tr>
<td>$\text{H}_3\text{PO}_4$(s)</td>
<td>-1279</td>
</tr>
<tr>
<td>$\text{H}_3\text{PO}_4$(l)</td>
<td>-1267</td>
</tr>
<tr>
<td>$\text{H}_3\text{PO}_4$(aq)</td>
<td>-1288</td>
</tr>
</tbody>
</table>

$$\Delta H_{\text{ron}} = \sum n_p \Delta H_{f,p} - \sum n_y \Delta H_{f,y}$$

$$= [3(-1433) + 2(-1267)] - [4126 + 3(-814)]$$

$$= -4299 - 2534 - 4126 - (-2442)$$

$$= -6833 + 6568$$

$$= -265\text{kJ}$$

5. (12 points) Define or give mathematical equation for the following terms:

**Wavelength** This distance between two consecutive peaks in a waveform.

**Standing wave** - A waveform that oscillates in place and does not move in one direction.

**Enthalpy** - $H = E + PV$ The internal energy of a system + a term that takes into account the pressure and the volume of a system. $\Delta H = q_p$

**Calorimetry** - The measurement of heat gain or loss in a physical process.
6. One reason that X-rays are damaging to your body is that they carry enough energy to break chemical bonds in your DNA, thus disrupting your genetic information.

A. (6 points) How much energy is contained in one mole of photons from an X-ray with a wavelength of 14.8 nm

\[ E = \hbar \nu = h \frac{c}{\lambda} \]
\[ = (6.626 \times 10^{-34} \text{J} \cdot \text{s} \times 3.0 \times 10^{8} \text{m/s})/14.8 \times 10^{-9} \text{m} \]
\[ = 1.34 \times 10^{-17} \text{J per photon} \]
1 mole of photons = 6.022 \times 10^{23}

\[ E \text{ of 1 mole of photons} = 1.34 \times 10^{-17} \times 6.022 \times 10^{23} \]
\[ = 8090 \text{kJ/mole} \]

B. (6 points) Calculate the mass associated with a photon of X-ray radiation with a wavelength of 14.8 nm

\[ m = \frac{h}{\lambda c} \]
\[ = 6.626 \times 10^{-34} \text{J} \cdot \text{s} / (14.8 \times 10^{-9} \text{m} \times 3.0 \times 10^{8} \text{m/s}) \]
\[ = 1.49 \times 10^{-34} \text{kg} \]

7. (12 points) Calculate the energy associated with an electron moving from the n=10 to n=3 orbital using the Bohr model. The equation that Bohr used in his model was

\[ E = -2.178 \times 10^{-18} \text{J} \left( \frac{Z}{n^2} \right) \]

\[ Z = +1, \ 1^2 = 1 \]
\[ n_{\text{initial}} = 10, \ E_{\text{initial}} = -2.178 \times 10^{-18} \text{J}(1/10^2) = -2.178 \times 10^{-20} \text{J} \]
\[ n_{\text{final}} = 3, \ E_{\text{final}} = -2.178 \times 10^{-18} \text{J}(1/3^2) = -2.420 \times 10^{-19} \text{J} \]

\[ \Delta E = E_{\text{final}} - E_{\text{initial}} = -2.420 \times 10^{-19} \text{J} - (-2.178 \times 10^{-20} \text{J}) \]
\[ = -2.202 \times 10^{-19} \text{J} \]

Is this energy emitted by the atom or absorbed by the atom?

Negative sign means that energy left the system so energy had to be emitted.
8. (12 points) For each of the four quantum numbers associated with an atom give the name of the quantum number, its usual abbreviation, its physical meaning, and its range of values.

<table>
<thead>
<tr>
<th>Name</th>
<th>Abbreviation</th>
<th>Physical meaning</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Principle Quantum Number</td>
<td>n</td>
<td>size of energy</td>
<td>Integers &gt;0</td>
</tr>
<tr>
<td>Angular momentum #</td>
<td>ℓ</td>
<td>shape</td>
<td>Integer ≥0, ≤n-1</td>
</tr>
<tr>
<td>Magnetic Quantum #</td>
<td>mₗ</td>
<td>orientation</td>
<td>Integers ≥-ℓ, ≤+ℓ</td>
</tr>
<tr>
<td>Electron spin Quantum #</td>
<td>mₛ</td>
<td>Electron spin</td>
<td>+1/2 or -1/2</td>
</tr>
</tbody>
</table>