Chapter 11 – Homework solutions

Problem # 2 Determine the kinds of intermolecular forces present in each element or compound:

A. Kr
B. NCl_3
C. SiH_4
D. HF

SOLUTION: Kr is a single atom, hence it can have no permanent dipole. The only possible force is a (weak) van der Waal's force.

NCl_3 will have van der Waal's force (everything does). The other forces depend on the existence of a dipole, so I look at the electronegativies. N is 3.0 and so is Cl. So, no electronegativity difference, no permanent dipole.

Same basic analysis for SiH_4. It has van der Waal's forces. The electronegativity of Si 1.8 and H is 2.1. That is below 0.5 difference (2.1-1.8) so the bond itself is considered to be non-polar so no dipole forces.

HF has van der Waal's forces. The electronegativity of F is 4.0 compared to H 2.1. This is a big difference, almost ionic. H bonded to F, O, N causes "hydrogen bonding" which is just really strong dipole/dipole interaction.

Problem # 24 A 45.0 mL sample of water is heated to its boiling point. How much heat is required (in kJ) to vaporize it? (Assume a density of 1.0 g/mL.)

SOLUTION: The energy required to make the phase transition is the ΔH_{vap}. For water at 100°C, ΔH_{vap}=40.7 kJ/mol. Units! Units! Units! I have $\frac{kJ}{mol}$ and I want kJ. All I need to know is how many moles of water I have and I'm done! $\frac{kJ}{mol} mol = kJ$

I don't know moles, I do know mL…that's okay, I just convert the units!

$$45.0 \ mL \frac{1.0 \ g}{mL} \frac{1 \ mol}{18.02 \ g} = 2.50 \ mol \ H_2O$$

$$\frac{40.7 \ kJ}{mol} \ 2.50 \ mol = 102 \ kJ$$

Problem #26 Suppose that 1.02 g of rubbing alcohol (C_3H_8O) evaporates from a 55.0 g aluminum block. If the aluminum block is initially at 25°C, what is the final temperature of the block after the evaporation of the alcohol? Assume that the heat required for the evaporation of the alcohol comes only from the aluminum block and that the alcohol vaporizes at 25°C.

SOLUTION: This is really just a conservation of energy problem. The energy moves around but the total amount stays the same. The total change in energy for the system is 0. Or, in algebraic form:

$Q_{block} + Q_{alcohol} = 0$

The last sentence gives you two simplifying assumptions. "the heat...comes only from the aluminum block" is telling you that the air isn't part of the problem so you don't need to worry about other things in the room. The "alcohol vaporizes at 25°C" is informing you that the alcohol doesn't change temperature during the process.

If I consider my two heat terms:

$Q_{alcohol}$ is simply a change of state for the alcohol, so it is a $n\Delta H_{vap}$.

Q_{block} is a temperature change of the block (no phase change) so it is an $mc\Delta T$.

$m_{block}c_{Al}\Delta T_{block} + n_{alcohol} \ \Delta H_{vap,alcohol} = 0$

or

$m_{block}c_{Al}\Delta T_{block} =- n_{alcohol} \ \Delta H_{vap,alcohol}$

Recall that $\Delta T = T_f - T_i$

$m_{block}c_{Al}(T_{f,block} - T_{i,block}) =- n_{alcohol} \ \Delta H_{vap,alcohol}$

Let's look at what we know:

$m_{block} = 55.0 \ g$

$m_{alcohol} = 1.02 \ g$

$T_{i, \ block} = 25°C$

I can also look up the two physical constants:

C_{Al} = 0.903 J/(g°C)

$\Delta H_{vap, rubbing\ alcohol}$ = 45.4 kJ/mol (at 25°C)

I actually need moles of alcohol, not grams but if I look at my conservation of energy equation, I know everything but the T_f of the aluminum block.

$$1.02\ g\ alcohol\frac{1\ mol}{60.097\ g} = 0.01697\ mol\ alcohol$$

$$55.0\ g\ Al\ \frac{0.903\ J}{g°C}\left(T_f - 25°C\right) = -0.01697\ mol\ alcohol\frac{45.4\times10^3 J}{mol}$$

(notice that I converted the kJ to J so that I have J on both sides of the equation.

$$49.665\ T_f - 1241.7 = -770.5543$$

$$49.665T_f = 471.07$$

T_f = 9.5°C

Problem #30 Benzene has a heat of vaporization of 30.72 kJ/mol and a normal boiling point of 80.1 °C. At what temperature does benzene boil when the external pressure is 445 torr.

SOLUTION: Just a Clausius-Clapeyron equation

$$\ln\left(\frac{P_2}{P_1}\right) = \frac{-\Delta H_{vap}}{R}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)$$

It is important to remember what "normal" means. The "normal boiling point" is the boiling point at 1 atm (760 torr) of pressure. And recall that "boiling" occurs when the vapor pressure = atmospheric pressure.

So, I actually know more than it looks like at first glance.

P_1 = 760 torr

T_1=80.1°C

P_2=445 torr

T_2=?

ΔH_{vap} = 30.72 kJ/mol

R = 8.314 J/(mol K)

It is very important to have the units correct in a problem such as this.

The pressure units don't matter. They cancel in the ratio and all pressure units are proportional.

Since R has "Joules" in it, I need ΔH_{vap} to be in J so it cancels.

The other big issue is temperature. EVERY time you are talking energy, temperature must be on an absolute scale. You need zero temperature to correspond to zero energy. So, kelvins is it.

P_1 = 760 torr

T_1=80.1°C + 273.15 = 353.25 K

P_2=445 torr

T_2=?

ΔH_{vap} = 30.72 kJ/mol = 30.72x10³ J/mol

R = 8.314 J/(mol K)

Now it's just a plug and chug!

$$\ln\left(\frac{445\ torr}{760\ torr}\right) = \frac{-30.72 \times 10^3\ \frac{J}{mol}}{8.314\ \frac{J}{mol\ K}}(\frac{1}{T_2} - \frac{1}{353.25\ K})$$

$$\ln(0.5855) = -3695\ K(\frac{1}{T_2} - \frac{1}{353.25\ K})$$

$$-0.5353 = -3695\ K(\frac{1}{T_2} - \frac{1}{353.25\ K})$$

$$1.449 \times 10^{-4} = (\frac{1}{T_2} - \frac{1}{353.25\ K})$$

$$1.449 \times 10^{-4} = \frac{1}{T_2} - 1.4487 \times 10^{-4}$$

$$\frac{1}{T_2} = 2.976 \times 10^{-3}$$

$$T_2 = 336 \ K$$

Problem #36 How much heat (in kJ) is evolved in converting 1.00 mol of steam at 145.0 °C to ice at -50 °C? The heat capacity of steam is 2.09 J/g°C and of ice is 2.09 J/g°C.

SOLUTION: There's actually a typo here. The values for the heat capacity of steam and ice should NOT be the same. Steam is actually less. But I'll just solve it using the numbers they give you.

For ALL heating/cooling problems, you need to break up the energy journey of the substance into two different types of legs: keeping the phase and changing temperature or changing phase and keeping the temperature constant.

We start with 1.00 mol of steam at 145 C. This is above the normal boiling point of 100 C. So the first thing that happens if I start taking out energy is that the steam cools down to its boiling (condensing) point. This is an mCΔT problem.

$$1.00 \ mol \ H_2O \ \frac{18.02 \ g}{mol \ H_2O} = 18.02 \ g$$

$$Q = mC_{steam}\Delta T$$

$$Q = (18.02 \ g)\left(2.09\frac{J}{gC}\right)(100C - 145C) = -1694 \ J$$

The (-) sign just means that the heat is given off rather than absorbed.

Once I get to the boiling point, I can condense into liquid form. This is an nΔH problem. The heat of vaporization at 100 C is 40.7 kJ/mol. Since we are condensing not boiling, the enthalpy of condensation is -40.7 kJ/mol

$$Q = n\Delta H = 1.00 \ mol\left(\frac{-40,700 \ J}{mol}\right) = -40,700 \ J$$

Now I'm liquid water. I need to cool down to my freezing point before I'll freeze. This is an mCΔT problem again.

$$Q = mC_{steam}\Delta T$$

$$Q = (18.02 \ g)\left(4.18\frac{J}{gC}\right)(0C - 100C) = -7532 \ J$$

Now I'm at my freezing point, so I freeze!

$$Q = n\Delta H = 1.00 \; mol \left(\frac{-6020 \; J}{mol}\right) = -6020 \; J$$

Now I'm ice! I just cool down to my final temperature.

$$Q = (18.02 \; g)\left(2.09 \frac{J}{gC}\right)(-50C - 0C) = -1883 \; J$$

The total heat given off is just the sum of all the legs of the journey:

Q_{total} = -1694 J + (-40,700 J) +(-7532 J) + (-6020 J) + (-1883 J) = -57,829 J

Problem #38 Consider the phase diagram for iodine and answer each question.

A. What is the normal boiling point for iodine?
B. What is the melting point for iodine at 1 atm?
C. What state is present at room temperature and normal atmospheric pressure?
D. What state is present at 186 °C and 1.0 atm?

SOLUTION: Hard to explain in words, you just need to read the graph:

A. "normal" means at 1 atm. The intersection of the horizontal line at 1 atm with the vaporization curve is at 184.4 °C
B. The intersection with the fusion curve is at 113.6°C
C. Room temperature is about 25°C. So if you drop down below 113.6 C (the melting point at 1 atm), you are going to be a solid.
D. If you go right (higher) than 184.4 C (the boiling point at 1 atm) you are going to be a gas.