Examples of exercises you should be able to solve

Ideal gas law

a)

Helium has the ideal gas law equation of state

$$pV = Nk_bT$$

Where N is the number of Helium atoms, and k_b is boltzmann's constant.

We can rewrite this in terms of the number of moles of the gas n:

$$pV = nN_Ak_bT$$

Where n is the number of moles, and N_A is avogadro's constant.

We can also write this in terms of the mass of gas m by substituting $n = \frac{m}{M}$, where M is the molar mass (mass of one mole of Helium)

$$pV = \left(\frac{m}{M}\right)N_Ak_bT$$

$$pV = m\left(\frac{N_Ak_b}{M}\right)T$$

$$p = mR_s\frac{T}{V}$$

where R_s is the *specific gas constant*, in our case $2.07\ \text{kJ}\ \text{kg}^{-1}K^{-1}$

The expansion work p-V is:

$$dW = \int_{V_1}^{V_2} pdV$$

$$dW = \int_{V_1}^{V_2} \frac{mR_sT}{V}dV$$

$$\Delta W = mR_sT\ln\left(\frac{V_2}{V_1}\right)$$

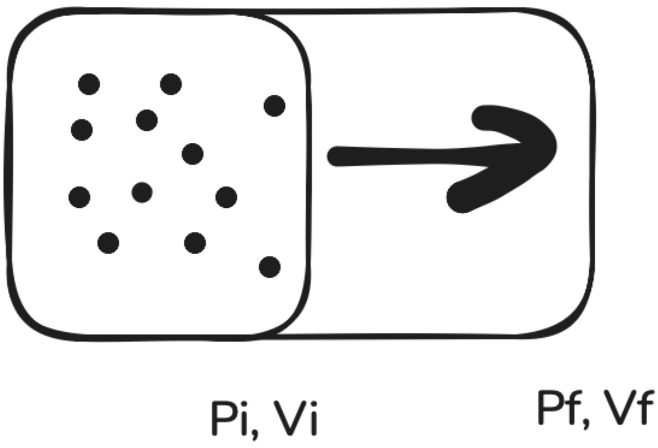

Figure 1: Diagram to show initial and final pressure, volume

The specific expansion work is

$$\frac{\Delta W}{m} = R_s T \ln\left(\frac{V_2}{V_1}\right)$$

For constant temperature, $\frac{V_2}{V_1} = \frac{p_1}{p_2}$

$$\frac{\Delta W}{m} = R_s T \ln\left(\frac{p_1}{p_2}\right)$$

Where $R_s = 2.07\ \mathrm{kJ\ kg^{-1}K^{-1}}$, and $T = 373K$, $\frac{p_1}{p_2} = 30$

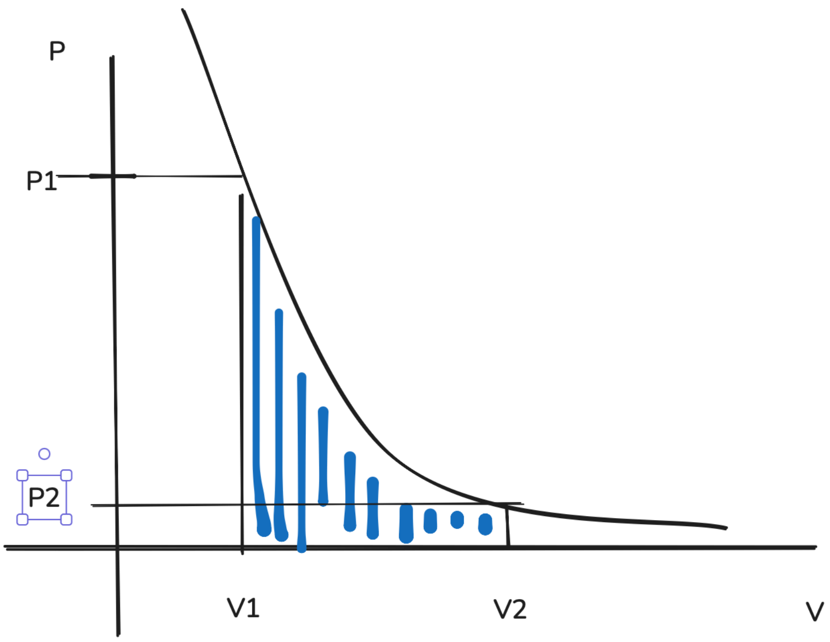

Figure 2: Blue area is the work done by the gas

We can do this calculation in the Python REPL:

```
>>> import math
>>> (2.07) * 373 * math.log(30)
2626.0985103551666
```

hence:

$$\Delta W = 2626 \text{ kJ kg}^{-1}$$

For an *isothermal* process of an ideal gas:

$\Delta T = 0 \to \Delta U = 0$

By the first law of thermodynamics, $\Delta U = Q - W$

Q is the energy added to the system as heat W is the work done by the system on its surroundings

The heat supplied to the gas equals the work done by it, since the internal energy isn't changing.

Hence, 2627 kJ kg^{-1} has to be supplied

Mass and Energy Balance