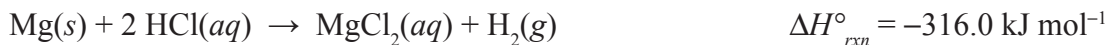


## NMSI Super Problem: Thermodynamics

Magnesium flakes were added to an open polystyrene cup filled with 50.0 mL of 1.00 M HCl solution. Assume the specific heat of the solution to be 4.18 J/g°C.



- If 0.650 g of the magnesium were added, determine the total amount of heat released into the calorimeter.
- Determine the temperature change in the calorimeter.
- Draw an energy profile diagram and label the enthalpy change,  $\Delta H$ , for the reaction.

The hydrogen gas produced in the reaction of magnesium and HCl was captured and placed in a sealed container, which occupies a volume of 650 mL at a constant pressure of 1.0 atm. The temperature of the container and gas was changed by 15°C; the resulting volume of the gas in the container is 620 mL.

- Is the temperature of the system increasing or decreasing. Justify your answer
- Calculate the amount of work done, in Joules (J).

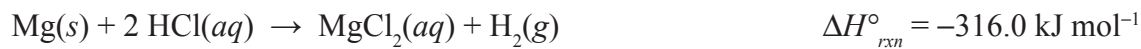
f. Is the statement in the box below correct? Justify your answer.

The gas collected in the container does work on the surroundings

Answer the following questions about the oxidation of magnesium metal.



g. Determine the value of the standard enthalpy change for the reaction in the box above.



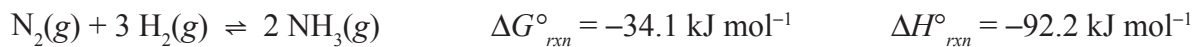
h. Determine the value of the standard entropy change,  $\Delta S_{\text{rxn}}^{\circ}$ , for the oxidation of magnesium using the information in the following table.

| Substance      | $\Delta S^{\circ} (\text{J mol}^{-1} \text{K}^{-1})$ |
|----------------|--|
| Mg             | 33   |
| O <sub>2</sub> | 205  |
| MgO            | 27   |

i. Calculate  $\Delta G_{\text{rxn}}^{\circ}$  for the oxidation of magnesium at 25°C

j. Indicate whether the reaction is thermodynamically favored at 25°C. Justify your answer.

The hydrogen gas collected and placed in the sealed container above is mixed with nitrogen gas to produce ammonia according to the Haber process shown below.



k. In terms of the equilibrium constant,  $K$  for the above reaction at  $25^\circ\text{C}$

i. Predict whether  $K$  will be greater than, less than, or equal to one. Justify your choice.

ii. Calculate its value.

l. In terms of the standard entropy change,  $\Delta S^\circ$

i. Predict the sign of  $\Delta S^\circ$  for the above reaction. Justify your answer.

ii. Calculate the value of  $\Delta S^\circ_{\text{rxn}}$  for the above reaction at  $25^\circ\text{C}$ .

m. Using the data in the table below and the enthalpy of reaction,  $\Delta H^\circ_{\text{rxn}}$ , calculate the approximate bond energy of the nitrogen–hydrogen bond in ammonia.

| Bonds | Approximate Bond Energy (kJ mol <sup>-1</sup> ) |
|-------|---|
| N—H   | ???   |
| H—H   | 430   |
| N≡N   | 960   |