Michael P. Jansen, Willowdale ON

Do less….better

A thermochemistry review problem for introductory chemistry

Reprinted from October 1999, page 32

Reg Friesen encouraged me to submit my chemistry teaching ideas for publication. His advice of "One idea per sentence" has become my credo.

The following is an excellent problem-solving review question for introductory chemistry. It involves writing and balancing a chemical equation, stoichiometry, enthalpy of reaction, and some good old-fashioned problem solving.

The problem

Students are presented with the following quotation from a newspaper article:

"a gigajoule is 0.95 thousand cubic feet of [natural] gas"[1]

I ask the students if they believe this. Some do; some don't. In any case, I then ask them to determine if this statement is true.

The problem requires students to:

- assume that natural gas is methane, CH_4;
- think about the quotation and realize that it involves not methane *per se*, but the [complete] *combustion* of methane;
- write a balanced chemical equation for the complete combustion of methane;
- calculate the enthalpy of reaction for the complete combustion of methane using the Hess' Law equation,[2]
  $\Delta H_r = \Sigma\Delta H_f(\text{products}) - \Sigma\Delta H_f(\text{reactants})$; (eq. 1)
- perform stoichiometric calculations with gases at STP;
- look up conversion factors for imperial units to metric, and perform the necessary conversions.

Sample calculation

The statement is based on the combustion of natural gas. For simplicity, we assume that natural gas is made up entirely of methane, CH_4. The balanced equation for complete combustion of methane is:

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$. (eq. 2)

Using eq. 1 and tabulated values for ΔH_f[2] we have:

ΔH_r = [-393.5 kJ + 2(-241.8) kJ] - [-74.8 kJ], or

ΔH_r = -802.3 kJ per mol CH_4 burned.

These conversion factors are needed:

1 inch = 2.54 cm

1 foot = 12 inches

1 litre = 1000 cm^3 (or 1 dm^3)

Accordingly,

1 foot = 12 inches x (2.54 cm/inch) = 30.48 cm

and 1 cubic foot = $(30.48\ cm)^3$

or 1 $foot^3$ = 28,317 cm^3

or 1 $foot^3$ = 28.3 L (to 3 significant figures)

Therefore, 0.95 thousand cubic feet is:

950 ft^3 of CH_4 x (28.3 L/$foot^3$) = 2.69 x 10^4 L of CH_4

Converting this volume of methane to moles at STP gives

2.69 x 10^4 L/(22.4 L/mol) = 1201 mol of CH_4.

Now: 1201 mol x 802.3 kJ/mol = 9.6 x 10^5 kJ

or 9.6 x 10^8 J

or 0.96 GJ

This is within 5% of the one gigajoule mentioned in the quotation. Considering our assumptions (STP and that natural gas is pure methane), the statement is true. Students who use the ΔH_f for $H_2O(l)$ as opposed to $H_2O(g)$ will obtain a value of 1.07 GJ, also within our margin of error.

Encourage your students to examine their assumptions in order to find the most likely explanations for the 5-7% discrepancy; this might involve inquiries at their local natural gas supplier.

References

1. Brent Jang, "Cold hits domestic supplies of gas —Heating bills soar for Canadians", *The Globe and Mail*, January 16, 1997, page A1.
2. Any introductory text, such as Wilbraham et al, *Chemistry (SI edition)*, Addison Wesley, Don Mills, 1993. ■

Solution to Element Anagrams, page 14

1. Hi, mule (helium)
2. Air bum (barium)
3. Iron gent (nitrogen)
4. Rib omen (bromine)
5. Emu arming (germanium)
6. Rum aid (radium)
7. Cumin teeth (technetium)
8. Cab lot (cobalt)
9. Pious mats (potassium)
10. Limp tuna (platinum)
11. Gnu tents (tungsten)
12. Noble dummy (molybdenum)