Reaction Energies – Problem Based Learning

Power the world with farts?

Student Problem

Would it be possible to power the world by burning the gases in people's farts?

You will need to make many approximations. Your goal is **not** to get an exact answer but to see whether it would be even feasible to investigate the potential of this claim further. Could we power Earth a million times over using the power of farts, or could we not even power a single house?

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Enthalpy – Problem Based Learning

Power the world with farts?

TEACHER'S GUIDE

This activity would best be completed in groups on a whiteboard (or similar). Afterwards, time should be allocated for each group to present their findings and for groups to discuss and critique each other's assumptions, approximations and results, where appropriate.

Students are inevitably going to need to estimate things in this problem. It's important to emphasise that the goal is not to get a precise number, but to see whether this is feasible or not (is it *about* right or *nowhere near* the right amount).

Encourage students to use the order-of-magnitude approach to estimates, it is very useful. To estimate something, increase/decrease a guess by an order of magnitude (multiply or divide by 10) and decide which one seems more reasonable. Emphasise that it's also important for students to keep track of their units!

> *e.g. How many pencils would need to be stacked on top of each other to be as tall as the Eiffel tower? A pencil is about 10 cm long (it's certainly longer than 1 cm, but less than 1 m). The Eiffel tower is about 100 m tall (it's more than 10 m, but less than 1 km). 10 cm = 0.01 m, so* $\frac{100m/tower}{0.01m/pencil} = \frac{10^2}{10^{-2}} pencils/tower = 10^4 pencils/tower = 1000\, pencils/tower.$

Data should be provided to students only when they ask for it and if deemed necessary (i.e. difficult or impractical to estimate). Make it clear at the start that you're able to provide information that students may require, encourage them to ask questions of you and their peers. Depending on school policy students may be allowed to use the internet to find some of their own data, however this is not the primary goal of this exercise.

Hints and advice:

One way to start would be to work out how much a person farts in a day. Estimates for flatus (fart gas) should be on the order of 1 L of flatus each day. Anything from 100 mL to a few litres is perfectly fine. If students' estimates are wildly different, ask them how they came up with their estimate. There's certainly nothing wrong with different estimates and they are free to use whatever they want, it may however be useful for them to revaluate how they came up with their estimate and if it seems reasonable, especially at this early stage of the calculation.

Next, they could consider what parts of flatus are flammable (they could estimate this themselves or use the data given: see composition of flatus below). There isn't a definitive reliable source on the composition of flatus, ultimately, it's up to students how they want to use the data; they could go for the ideal or worst case-scenarios, or anything in between. As a comparison, we used 400 mL of H_2 and 100 mL of CH_4.

Students will then hopefully realise they will need to know the enthalpy of combustion for hydrogen and methane to work out the energy released. We made the ideal assumption that 100% of the energy released could be harnessed, in reality it would be less. Students will likely do this to.

Depending on how they're proceeding, you could ask proficient students how they would harness this energy, and whether it would be plausible to get 100% *useful* energy out.

There are numerous ways of working out the amount (number of moles) of gas from the volume of a typical flatus. These could include density calculations or using the ideal gas equation. We used the ideal gas equation at 1 atm and 298 K. What's important is that students are able to understand their approximations and justify their approach. (Lots of numbers provided below)

Populations of Canberra, Australia and the world are given below. However, students should be encouraged to come up with their own estimates. Most will probably have a good idea of the populations of Australia and the world, and estimating a population for Canberra around 100,000 to 1 million would be reasonable.

The energy consumption of the world is a bit harder to estimate (especially in useful units) and may be best if provided to students (at the appropriate time).

It's important to remember that everyone will have their own estimates that will be different. Depending on individual estimates results will vary, but hopefully they should all be within one or two orders of magnitude of each other, enough to get an idea of whether it is feasible.

Groups which finish the initial problem early may wish to consider extensions of this (e.g. Can we power Australia or Canberra? What if we also used cow farts?) and are encouraged to come up with their own extensions.

Some possibly useful data students may ask for:

The composition of flatus varies, two different sources suggest:

- 75% (H_2, CO_2, CH_4), 25% (N_2, O_2), 1% smelly stuff
- 20-90% N_2, 0-50% H_2 (flammable), 10-30% CO_2, 0-10% O_2, 0-10% CH_4 (flammable)

Combustion of H_2: $2H_2 + O_2 \rightarrow 2H_2O$, ΔH = -572 kJ mol^{-1}

Combustion of CH_4: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, ΔH = -882 kJ mol^{-1}

$$PV = nRT$$

Molar volume of ideal gas: STP (0.00 °C, 1.00 atm) = 22.4 L mol^{-1}, SLC (25 °C, 1.00 atm) = 24.5 L mol^{-1}

Various gas constants:

Value of R	**Units (V P T^{-1} n^{-1})**
8.206×10^{-2}	L atm K^{-1} mol^{-1}
8.314×10^{3}	mL kPa K^{-1} mol^{-1}
8.314	L kPa K^{-1} mol^{-1}

Densities of various gases (at STP):

Substance/Mixture	**Density (kg m^{-3})**

Air	1.292
Methane	0.708
Hydrogen	0.0899

Energy consumption in Australia per year (2014-2015)[1] = 5,920 PJ = 5.92×10^{18} J

	Population	Energy Produced (kJ day^{-1})	Energy Consumed (kJ day^{-1})
World	7.6×10^{9}	6.3×10^{10}	1.6×10^{15}
Australia	2.4×10^{7}	2.0×10^{8}	1.6×10^{13}
Canberra	3.6×10^{5}	3.0×10^{6}	2.4×10^{11}

Above is a quick summary of some results we got so you can check students are on the right track or if something has gone awry. (Assumed 500 mL flammable gas/day: 100 mL CH_4, 400 mL H_2. Energy Produced = 8.3 kJ $person^{-1}$ day^{-1})

[1] A Ball, S Ahmad, C McCluskey, P Pharm, I Ahn, L Dawson, T Nguyen, D Nowabowski, Australian Government: Department of Industry, Innovation and Science, *Australian Energy Update*. Retrieved 28/6 from https://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/aes/2016-australian-energy-statistics.pdf