**POLL QUESTION**

Determine the relative energy of the bonds being broken

\[ CH_4 + \frac{5}{2} O_2 \rightarrow CO_2 + CO + 2H_2O \]

a) None of the others (below)

b) 10.0

c) 8.0

d) 7.8

e) 7.0

<table>
<thead>
<tr>
<th>Bond</th>
<th>Energy (kJ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C = O</td>
<td>2.0</td>
</tr>
<tr>
<td>O = O</td>
<td>1.2</td>
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<tr>
<td>O − H</td>
<td>1.1</td>
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<tr>
<td>C − H</td>
<td>1.0</td>
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<tr>
<td>C − C</td>
<td>1.0</td>
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</tbody>
</table>

1 unit ≈ 410 kJ
Determine the relative energy of the bonds being broken

$$CH_4 + \frac{5}{2}O_2 \rightarrow CO_2 + CO + 2H_2O$$

Relative Bond Energy $CH_4 = 4$

Relative Bond Energy $\frac{5}{2}O_2 = 3.0$

Relative Energy of Bonds Broken = 7.0

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>$C = O$</td>
<td>2.0</td>
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<tr>
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<td>1.0</td>
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</table>
World Energy Supply

1. Petroleum
2. Natural Gas
3. Coal
4. Renewable Energy
5. Nuclear
Coal Reserves

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Natural Gas Consumption

- Current: $3 \text{Tm}^3/\text{yr}$
- Expected to double in the next 50 years.
US Shale Gas Production

Where Does Electricity Come From

U.S. electricity generation by major energy source, 1950-2019


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Climate Change Believers/Deniers

There are 6 distinct audiences in the United States.

Source: Yale Program on Climate Change Communication
Alarmed

• The alarmed are fully convinced of the reality and seriousness of climate change and are already taking action to address it.
Concerned

• The concerned are also convinced that climate change is happening and that it is a serious problem, but have not yet engaged the issue personally.
Cautious

• The **cautious** are not sure if climate change is happening or if it is human caused.
Disengaged

• The disengaged don’t know anything about it.
The doubtful either don’t think climate change it is happening or think it is natural and not a threat. Not taking action either way.
Dismissive

- The dismissive are convinced climate change is not happening and that is a hoax.
- Oppose climate action and are actively involved as opponents of efforts to reduce greenhouse gas emissions.
POLLING QUESTION

Where do you fall?

a) Alarmed
b) Concerned
c) Cautious
d) Doubtful
e) Dismissive

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<tbody>
<tr>
<td>A</td>
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<tr>
<td>B</td>
<td>23</td>
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<tr>
<td>C</td>
<td>5</td>
</tr>
<tr>
<td>D</td>
<td>0</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
</tr>
</tbody>
</table>
About 67% of the US population is inclined to believe that climate change is real (Alarmed+Concerned+Cautious).
2018

December 2018
n=1,114

29% Alarmed
30% Concerned
17% Cautious
5% Disengaged
9% Doubtful
9% Dismissive

Highest Belief in Global Warming
Most Concerned
Most Motivated

Lowest Belief in Global Warming
Least Concerned
Least Motivated

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In 14 years 9% of the population has transitioned from Group 2 to Group 1.
Carbon Stabilization Revisited

The bad news 😞:
• Business as usual (BAU) likely lead to disastrous consequences.

The good news 😊:
• Stabilizing at roughly double current carbon levels seems possible.
• This will leave us until 2040ish to achieve a net-zero increase in $CO_2$ concentration.
• Most likely temperature change: $3^\circ C$ (5.4$^\circ F$)
Stern’s “Temperature Increases and Potential Risks”

- **Food**
- **Water**
- **Ecosystems**
- **Extreme Weather Events**
- **Runaway G. Effect**
The Kaya Identity

The Kaya Identity: States that the total $CO_2$ emission levels can be expressed as the product of four factors:

1. Population
2. GDP per Capita
3. Energy Intensity
4. Carbon Intensity
The Kaya Identity

\[ F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \]

\[ F \rightarrow \text{CO}_2 \text{ Emissions} \]

\[ P \rightarrow \text{Population} \]

\[ G \rightarrow \text{Gross Domestic Product (GDP)} \]

\[ E \rightarrow \text{Energy} \]
The Kaya Identity

\[ F = P \times \frac{G}{P} \times \frac{E}{G} \times \frac{F}{E} \]

Goal is to return yearly G.H.G. concentration to about 1/2 of today's levels.

Need to reduce G.H.G. emissions per energy used \((F/E)\) by about a factor of 5.
According to Stern’s “Temperature Increases and Potential Risks” graphic, which of the following will be affected by changes in temperature increases?

a) Food
b) Water
c) Extreme Weather Events
d) all of the above
e) b and c
The Kaya Identity relates human factors to:

- a) total $CO_2$ emission levels
- b) the amount of fossil fuels burned
- c) energy efficiency
- d) increase in population
- e) global economic growth
Activity

Manufacturing Carbon Footprint (Averages):

- Gasoline Car: about 14 Tons of $CO_2$
- Electric Car: about 25 Tons of $CO_2$ (most of the excess is from producing the battery).

Other data:

- A typical gasoline vehicle produces about 4.6 metric tons of $CO_2$ (carbon dioxide) per year (this assumes average fuel economy of about 25 miles per gallon and driving about 12,000 per year).
- $1 \text{ mile} = 1.6 \text{ km}$, $1 \text{ Ton} = 1.0 \times 10^6 \text{ g}$
- On average, driving an electric car indirectly produces 0.202 kg of $CO_2$ emissions per km.