EGEE 470
Midterm Exam

Read the following statements carefully and indicate whether they are true or false. For full credit (if correct) or partial credit (if incorrect), be sure to summarize how you reached your conclusions.

Note: There is no need to ask questions; if you feel that some statements are ambiguous, or require additional information, make convenient and reasonable assumptions.

T If the concentration of CO₂ at 300 K and 0.90 atm is 100 mg/m³, it does not exceed the current global average of 415 ppm.

\[
\frac{C_i RT}{P} = \frac{(100 \text{ mg})}{(0.08206 \text{ mol atm})} \times \frac{(1 \text{ mol})}{(418 \text{ J/mole K})} \times (300 \text{ K}) \times 0.90 \text{ atm} = 62.2 \times 10^6 = 62.2 \text{ ppm}
\]

T If the equilibrium constant for the reaction 0.5N₂ + 0.5O₂ = NO is 4.576e^(-10872/T), the equilibrium molar concentration of NO in air does not exceed 5000 ppm at 2000 K and 10 atm.

\[
K = \frac{y_{NO}}{y_{N_2}^{0.5} y_{O_2}^{0.5}} = 0.02 = \frac{4x}{(1-x)^2} \Rightarrow x \approx 0.005 \Rightarrow y_{NO} \approx 0.005
\]

T Assuming that the NOx AP-42 factor is 12 lb NO₂ per ton of subbituminous coal (10,000 BTU/lb), the NOx emissions from a 'typical' power plant (800 MW and 35% efficiency) do not exceed 100 tons per day.

\[
\frac{12 \text{ lb NO}_2}{\text{ ton coal}} \times \frac{1 \text{ lb}}{10^4 \text{ BTU}} \times \frac{1 \text{ BTU/kWh}}{0.35 \text{ BTU/kWh}} \times \frac{1 \text{ kWh}}{0.33 \text{ kWh}} \times \frac{1 \text{ ton}}{800 \text{ MW} \times 24 \text{ h}} \times \frac{1 \text{ day}}{1 \text{ ton}} = 56 \frac{\text{ t NO}}{\text{ d}} (\text{< 100 t/d})
\]

T The air-to-fuel requirement for stoichiometric ethanol combustion is less than 50% lower than that of octane combustion.

\[
C_{3}H_{6}O + 3 O_{2} + x N_{2} = 2 CO_{2} + 3 H_{2}O + (3/2)N_{2} \Rightarrow \frac{A}{F} = 8.95 \frac{\text{ g air}}{\text{ g fuel}}
\]

\[
C_{12.5}H_{18} + 12.5 O_{2} + x N_{2} = 8 CO_{2} + 9 H_{2}O + (12.5/3.76)N_{2} \Rightarrow \frac{A}{F} = 15.1 \frac{\text{ g air}}{\text{ g fuel}}
\]

\[
\text{Ratio} = \frac{8.95}{15.1} = 59 \text{%} \Rightarrow 41 \text{% lower}
\]
If the average diameter of the molecules is 0.35 nm and the average molecular mass is 0.030 kg/mol, kinetic theory of gases predicts that the diffusion coefficient does not exceed $1.0 \times 10^{-5}$ m$^2$/s at 320 K and 5 atm.

$$D = \frac{1}{3} \lambda c = \frac{RT}{6Td^2 N_A} = 1.6 \times 10^{-8} \text{ m}^2/\text{s}$$

$$\lambda = \frac{9.0 \times 10^{-7} \text{ m}^2}{(2.5 \times 10^{-6} \text{ m})^2} \leq (1.0 \times 10^{-5})$$

Using the constant initial NO formation rate, the quantity of NO formed after 0.5 s at 1800 K and 1 atm air does not exceed the equilibrium quantity of NO. (Hint: The dissociation Gibbs energy change for $O_2 + 2O = 2O_2$ is 270 kJ/mol.)

$$K = \frac{[O][O]^2}{[O_2]^2} \exp\left(-\frac{270000}{8.314 \times 1800}\right) = 1.46 \times 10^8$$

Based on the attached graphs, indicate whether the following statements are true or false.

**F** If the U.S. CO$_2$ emissions were 4421 and 5144 million metric tons in 1975 and 2015, combustion inefficiency (expressed as % incomplete combustion) has been reduced by less than 100% during this period.

$$\frac{4421 \times 10^6}{1975} = 22.8\%$$

$$\frac{5144 \times 10^6}{2015} = 1.7\%$$

**T** In 2017 the CO emissions from vehicles did not exceed 50% of the total CO emissions.

**T** Both the temperature and the pressure effect on the SO$_2$/SO$_3$ ratio are consistent with LeChatelier’s principle.

If the equilibrium mole fraction of O$_2$ were 0.25 at 2000 K and 10 atm, the equilibrium constant would not exceed 0.010.

$$k = \frac{[SO_3]}{[SO_2][O_2]^{0.5}} = \frac{0.03}{0.02^{0.5} \times 0.25^{0.5}} = \frac{1}{0.025 \times 0.25^{0.5}} = 0.006$$

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