CHEM 323: Applied Physical Chemistry

Thursday 8 June 2006

Answer **ALL** questions.

All questions are of equal value.

Write your answers in the answer book provided. Start each question on a new page.

TIME ALLOWED: 2 hours

---

1. The final stage in the production of synthetic petrol is the conversion of dimethyl ether to hydrocarbon. This can be represented approximately by the following equation:

$$n\mathrm{CH_3OCH_3} \rightarrow 2(\mathrm{CH_2})_n + n\mathrm{H_2O}$$

(a) Given that the temperature of the reaction stream must not rise by more than 100 K, calculate, using the information given below, the amount of inert gas (methane) that must be added to the reaction stream. Your answer should be given in terms of moles of inert gas per mole of dimethyl ether.

(b) If the throughput of dimethyl ether is 2000 tonnes per day, calculate the cooling that is required to return the methane to the original temperature of the inlet stream.

Mean molar mass of product hydrocarbon / (g mol^{-1})	126
Enthalpy of formation of the hydrocarbon / (kJ mol^{-1})	$-(50 + 20n)$
Enthalpy of formation of dimethyl ether / (kJ mol^{-1})	-184
Enthalpy of formation of water / (kJ mol^{-1})	-242
Heat capacity of product hydrocarbon / (J mol^{-1} K^{-1})	$(5 + 23n)$
Heat capacity of water / (J mol^{-1} K^{-1})	34
Heat capacity of methane / (J mol^{-1} K^{-1})	36

2. Write a short account of the manufacture of sulfuric acid as carried out at the Hornby plant of Ravensdown Fertiliser Co-op Ltd. You may wish to include in your answer discussion of the chemistry involved, energetics, choice and source of raw material, uses, and any other relevant chemical or economic matters.

3. During the spring warming in Antarctica (October – November) there is a substantial depletion of ozone. This depletion can extend to the latitudes of countries like New Zealand.

   (a) Give reasons why this ozone depletion occurs. In your discussion, comment on the role played by chlorine reservoirs such as $ClONO_2$ and HOCl and polar stratospheric clouds.

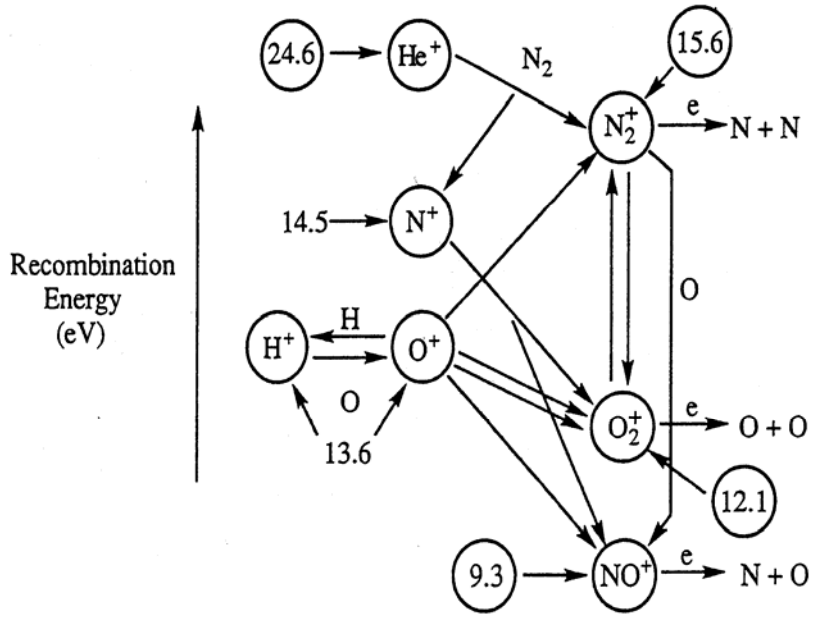
   (b) How long, in your opinion, is this depletion likely to continue?

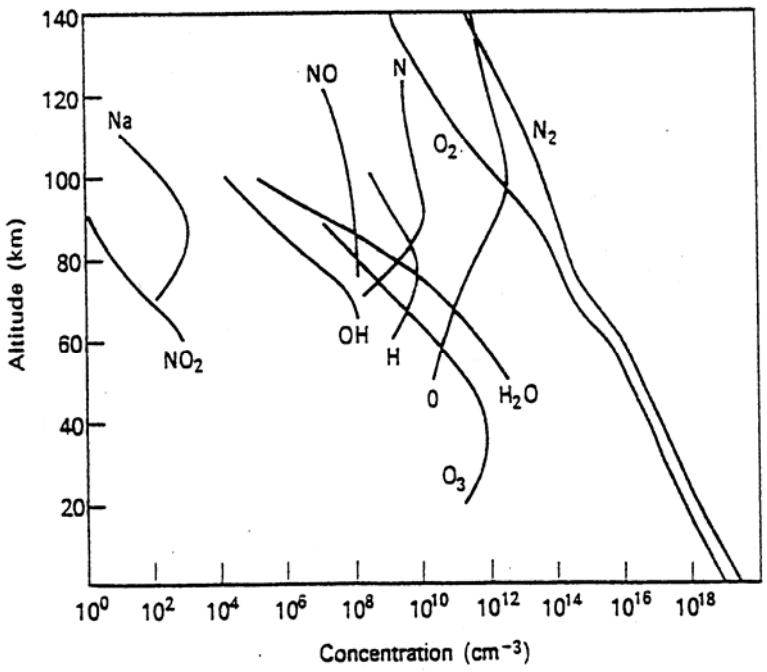
4. Referring to the figure below:

(a) Discuss the primary sources of ionization in the F region, E region and D region of the Earth's ionosphere;

(b) Contrast the ion chemistry of the F region with that of the D region.

In your comments pay particular attention to the recombination reactions that limit the extent of ionization.





Representative concentration profiles of neutral species in the atmosphere.

5 (a) For an industrial electrolysis process, the cell operating potential can be expressed as:

$$E^{cell}_{applied} = E^{cell}_{e} - |\eta c| - |\eta a| - |iR_{soln}| - |iR_{mem}|$$

(i) Explain why each term on the right hand side of the equation contributes to the cell operating potential.

(ii) For the chlor-alkali process for the production of Cl_2 and NaOH, describe how each of these terms can be minimised by choice of operating conditions, cell design and cell components. (Your answer should include a description of typical operating conditions, cell design and cell components).

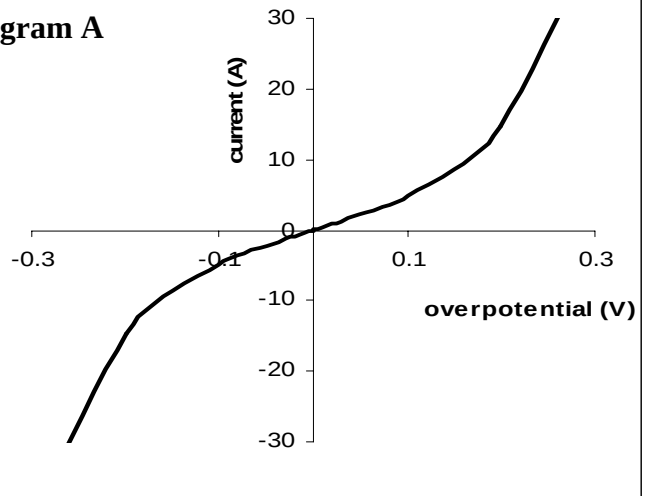
(b) **Diagram A** below shows a current-overpotential curve, and **Diagram B** (on the next page) the corresponding Tafel plot for the redox couple:

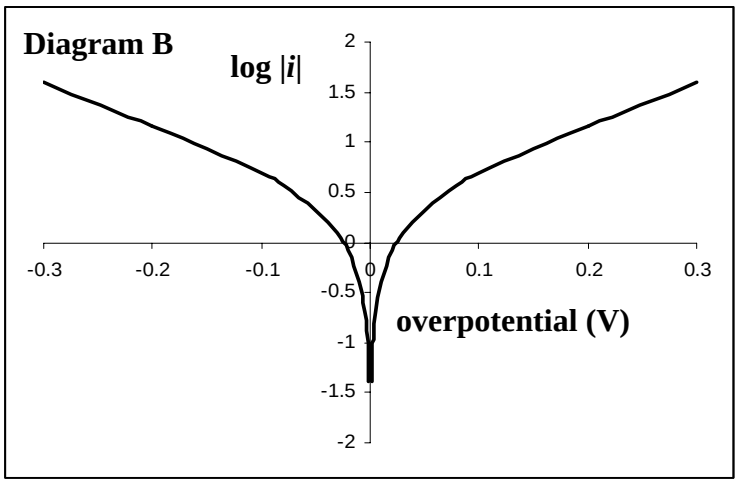
$$O + e^- \leftrightarrow R$$

(i) Explain how the exchange current can be determined from a Tafel plot.

(ii) Account for the deviation from linearity of the Tafel plot, when the overpotential is close to zero.

Diagram A





6. (a) Corrosion occurs on a metal surface through the formation of anodic and cathodic zones. Sketch a diagram of a corrosion cell, labelling the anodic and cathodic zones, indicating the polarity and the reactions occurring at each zone (assume that the oxidising agent is O_2). Show the electron and ion flow in the cell.

(b) Explain why the corrosion of a metal pipe that was exposed to the atmosphere, is found to be worst behind a bracket supporting the pipe. You should use a log|*i*| *vs E* diagram to assist your answer.

(c) Answer **one** of **either (**i), (ii) or (iii) below.

(i) Use labelled diagrams to explain why silicon (a group 14 element) can become electrically conducting after doping with phosphorous (a group 15 element) or boron (a group 13 element). Indicate whether the diagrams depict n-type or p-type doping.

(ii) Explain how a conventional silicon solar cell functions. What are the limitations of conventional silicon solar cells?

(iii) What is a quantum dot? What properties of quantum dots make them potentially useful materials for use in solar cells? What are the limitations of prototype quantum dot plastic solar cells?

END OF PAPER