'THE ATMOSPHERE' TEST

60 marks (1 hour)

1 Chlorofluorocarbons (CFCs) have been widely used as propellants, blowing agents and cleaning solvents, but their use leads to environmental damage in the atmosphere. As a result, alternative compounds are now being used. Some alkanes have been used; other common replacements are HFCs (hydrofluorocarbons) and HCFCs (hydrochlorofluorocarbons). Here are some data for three compounds: a CFC, an alkane and an HCFC.

Compound	Formula	Boiling point/K	Flammable	ODP*	Price
A	$CFCl_3$	297	no	1.0	medium
B	$CH_3CH_2CH_3$	231	yes	0.0	low
C	CF_3CCl_2H	302	no	0.02	high

*ODP is the Ozone Depletion Potential

a Suggest why compound **B** cannot be used as cleaning solvent. *(1 mark)*

b Suggest a *disadvantage* of using compound **C** as a replacement for compound **A**. *(1 mark)*

c HFCs and HCFCs are more reactive than CFCs and are broken down in the troposphere. The first step in this process involves reaction with OH radicals. **Equation 1.1** shows the reaction of compound **C** with OH radicals.

$$CF_3CCl_2H + OH \rightarrow CF_3CCl_2 + H_2O \qquad \textbf{Equation 1.1}$$

i Draw a dot-cross diagram (showing the outer electron shells only) which shows why OH is called a *radical*. *(3 marks)*

ii Give the formula of another radical in **Equation 1.1**. *(1 mark)*

iii Explain why **Equation 1.1** is called a *propagation* step. *(2 marks)*

d The reaction in **Equation 1.1** is important because it removes HCFC molecules from the troposphere before they can reach the stratosphere. By contrast, CFCs are unreactive until they reach the stratosphere.

Explain in detail the effect of CFCs on the ozone in the stratosphere, and how this affects human health. *(5 marks)*

e The bond enthalpy of the O–H bond is $+463\,kJ\,mol^{-1}$.

i Calculate the minimum energy required to break a *single* O–H bond. (Avogadro constant, $L = 6.02 \times 10^{23}\,mol^{-1}$.) *(2 marks)*

ii Calculate the minimum frequency of radiation needed to break the O–H bond. (Planck constant, $h = 6.63 \times 10^{-34}\,J\,Hz^{-1}$.) *(3 marks)*

iii Suggest why OH radicals are **not** produced in the troposphere by the action of sunlight on water molecules, but by another route. *(2 marks)*

[TOTAL: 20 MARKS]

(Adapted from OCR Chemistry (Salters), Paper 2, question 3, 1992)

2 The following quotation is taken from a DETR (Department of the Environment, Transport and the Regions) publication dealing with climate change.

The Sun is the Earth's only external source of heat. When solar radiation, in the form of visible sunlight, reaches the Earth, some is absorbed by the atmosphere and reflected from clouds and land (especially from deserts and snow). The remainder is absorbed by the surface which is heated and in turn warms the atmosphere. The warm Earth also radiates back into space but, being much cooler than the Sun, does so by giving off invisible infrared (i.r.) radiation.

The atmosphere is relatively transparent to solar radiation but many atmospheric trace gases absorb some of the infrared radiation emitted from the surface. As a result the atmosphere acts like a blanket preventing much of the infrared radiation from leaving the Earth.

a What is wrong with the statement which implies that solar radiation is 'in the form of visible sunlight'? *(2 marks)*

b **i** One of the 'trace gases' in the atmosphere is carbon dioxide. It is called a 'greenhouse gas' because its molecules absorb some of the i.r. radiation that the Earth re-radiates. Describe what happens to the molecules when they absorb i.r. radiation. *(2 marks)*

ii Name another trace gas in the atmosphere that acts as a greenhouse gas. *(1 mark)*

c The proportion of carbon dioxide in the atmosphere is increasing.

i Give **one** source of this increase. *(2 marks)*

ii Explain, in terms of the effect on molecules in the air, why the increase may cause global warming. *(2 marks)*

d The rise in the carbon dioxide concentration in the atmosphere is less than might be expected from calculating the increase in emissions, because some of the carbon dioxide dissolves in the oceans.

$$CO_2(g) + aq \rightleftharpoons CO_2(aq)$$

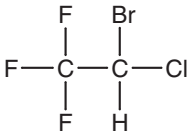
i This reaction can reach *dynamic equilibrium*. Explain what is meant by this term. *(3 marks)*

ii State *Le Chatelier's principle*, and show how it can be used to explain why the amount of carbon dioxide dissolved in the oceans is increasing. *(3 marks)*

iii State **one** way, that is under human control, of slowing down the rise in atmospheric carbon dioxide concentration. *(1 mark)*

[TOTAL: 16 MARKS]

3 The compound with the structure shown below is often called Fluothane. It is a widely used anaesthetic.



Fluothane

Fluothane is a halogenoalkane. Most halogenoalkanes are hydrolysed by water (or hydroxide ions). It is therefore possible that Fluothane is degraded by hydrolysis in the body.

a Give the systematic name for Fluothane. *(2 marks)*

b Name the technique that would be used to purify a sample of Fluothane, which is a liquid at room temperature. *(1 mark)*

c An attempt was made to hydrolyse some Fluothane in the laboratory by refluxing it with aqueous sodium hydroxide.

i Heating is used to speed up reactions. Explain, in terms of molecules and their energies, how this occurs. *(4 marks)*

ii Explain why the bromine atom in Fluothane is the most likely halogen atom to be substituted in a hydrolysis reaction. *(2 marks)*

iii Give the structural formula of the compound that would be formed if the bromine atom were substituted by OH in a hydrolysis reaction. *(2 marks)*

d The reaction described in **c** is described as nucleophilic substitution.

i Explain the meaning of the term *nucleophile*. *(3 marks)*

ii The nucleophile (OH^-) attacks the right-hand carbon atom in the Fluothane molecule drawn at the start of the question. Explain why this carbon atom is slightly positively charged, using the terms *electronegativity* and *bond polarity*. *(3 marks)*

e One way of preparing bromoalkanes is to react an alcohol with an aqueous solution of hydrogen bromide.

i Hydrogen bromide provides a high concentration of bromide ions, which are the nucleophiles in this reaction. Explain why a high concentration of reactant speeds up a reaction. *(2 marks)*

ii Hydrogen bromide also provides hydrogen ions, which act as a catalyst for the reaction. Catalysts of this type speed up reactions by forming an intermediate compound that subsequently reacts to form the product. This alternative route for the reaction has a lower activation enthalpy.

Draw a labelled *enthalpy profile* that illustrates this, showing the catalysed and the uncatalysed route. *(5 marks)*

[TOTAL: 24 MARKS]