OCR
RECOGNISING ACHIEVEMENT

AS GCE CHEMISTRY B (SALTERS)

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry B (Salters)* (inserted)
- *Advance Notice: 'Atmospheric Nitrogen'* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Inserts will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

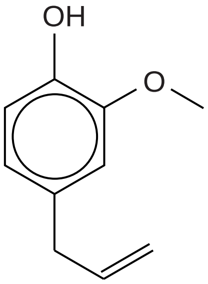
INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- ✎ Where you see this icon you will be awarded marks for the quality of written communication in your answer.

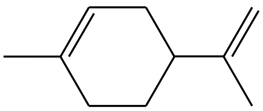
  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- The insert *'Atmospheric nitrogen'* is provided for use with question 5.

Answer **all** the questions.

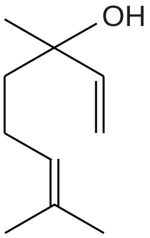
1 A car screen-wash product contains a mixture of eugenol, limonene and linalool.



eugenol



limonene



linalool

(a) **(i)** Name a functional group that is present in all three of these compounds.

.... **[1]**

(ii) Name a functional group that is present in eugenol but **not** in linalool (not the arene ring or the hydroxyl group).

.... **[1]**

(b) Limonene reacts with bromine.

(i) Draw the structure of the molecule that is produced from the reaction of a molecule of limonene with excess bromine.

[2]

(ii) Underline two words that describe the mechanism of the reaction between limonene and bromine.

addition **electrophilic** **nucleophilic** **radical** **substitution**

[2]

(iii) The impure liquid organic product of the reaction of limonene with bromine is dried after it has been prepared.

Name a drying agent that could be used.

.... **[1]**

(iv) Name the process that would be used to purify the liquid product.

.... **[1]**

(c) Limonene reacts with hydrogen.

Give the reagents and conditions for the reaction of limonene with hydrogen.

....

.... **[2]**

(d) Linalool contains an alcohol group.

(i) Classify the alcohol group in linalool as primary, secondary or tertiary.

.... **[1]**

(ii) Explain your answer to **(d)(i)**.

....

.... **[1]**

(iii) Linalool is heated with acidified potassium dichromate solution.

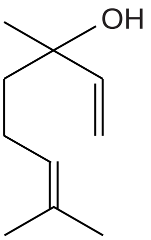
Describe and explain what you would **see**.

....

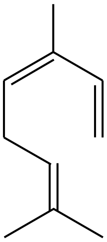
....

.... **[2]**

(e) When linalool vapour is passed over heated aluminium oxide at 300 °C, the linalool reacts to produce *Z*-ocimene.



linalool



***Z*-ocimene**

(i) Give the molecular formula of *Z*-ocimene.

.... **[2]**

(ii) The reaction producing *Z*-ocimene from linalool has an inorganic product.

Identify this product.

.... **[1]**

(iii) Underline the term below that describes the type of reaction that has occurred when *Z*-ocimene is produced from linalool.

addition **hydrolysis** **elimination** **substitution**

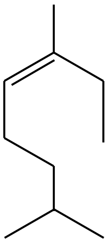
[1]

(iv) During the reaction that forms *Z*-ocimene from linalool, *E*-ocimene is also produced.

Draw a skeletal formula for a molecule of *E*-ocimene.

[1]

(f) *Z*-Ocimene reacts with hydrogen. One of the partially hydrogenated products of this reaction is shown below.

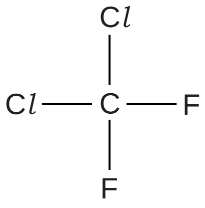


Give the systematic name of this compound.

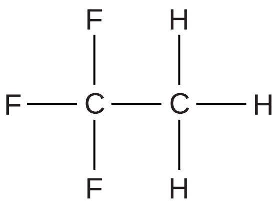
.... **[2]**

[Total: 21]

2 CFCs, such as CFC 12, were used as refrigerants. More recently, HFCs have taken over from CFCs because HFCs have much lower ozone depletion potentials. Examples of a CFC and an HFC are shown below.



CFC 12



HFC 143a

(a) What does *CFC* stand for?

.... **[1]**

(b) Give another large scale use for CFCs during the last century, other than as refrigerants.

.... **[1]**

(c) CFC 12 was made from tetrachloromethane, CCl_4, by reacting it with hydrogen fluoride.

(i) The reaction requires the use of a catalyst.

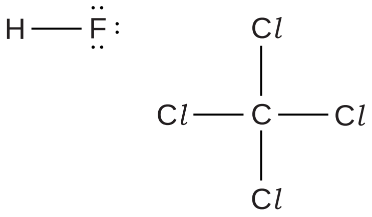
Explain how a catalyst increases the rate of a chemical reaction.

....

....

.... **[2]**

(ii) Add relevant partial charges and ‘curly arrows’ to the diagram to show the attack of one hydrogen fluoride molecule on tetrachloromethane and the resulting electron pair movement in the tetrachloromethane molecule.



[3]

(d) CFCs cause ozone depletion because their C–C*l* bonds break in the stratosphere when UV radiation is absorbed. The chlorine radicals that are produced catalyse the breakdown of ozone.

(i) Name the **type** of bond breaking process that occurs to form chlorine radicals from CFC molecules.

.... **[1]**

(ii) The bond enthalpy of the C–F bond is +467 kJ mol^{-1}.

Calculate the minimum energy (in Joules) needed to break a **single** C–F bond.

Avogadro constant, $N_A = 6.02 \times 10^{23}$ mol^{-1}

minimum energy = ... J **[2]**

(iii) Calculate the frequency of radiation that is needed to break a single C–F bond.

Give your answer to **three** significant figures.

Planck constant, $h = 6.63 \times 10^{-34}$ J Hz^{-1}

frequency = ... Hz **[3]**

(iv) Explain why C–F bonds are much less likely than C–C*l* bonds to be broken in the stratosphere.

....

....

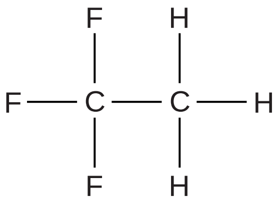
.... **[2]**

(v) In the 1980s, scientists researching the levels of ozone in the atmosphere discarded some of the data because they thought it was incorrect.

Explain why they thought the values were incorrect.

....

.... **[1]**



$$\begin{array}{ccccccc} & & F & & H & & \\ & & | & & | & & \\ F & - & C & - & C & - & H \\ & & | & & | & & \\ & & F & & H & & \end{array}$$

HFC 143a

(e) Give the systematic name for HFC 143a.

.... **[2]**

(f) HFC 143a is also a powerful greenhouse gas.

Explain how the ‘greenhouse effect’ enables energy from the Sun to be transferred to heat energy that warms the Earth’s atmosphere.

In your answer you should include:

- what happens to the radiation from the Sun that enters the Earth’s troposphere;
- what happens to a molecule of HFC 143a and how this results in the warming of the troposphere.

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.... **[5]**

(g) Give the evidence for the relationship between the increased concentration of greenhouse gases in the atmosphere and global warming.

....

.... **[1]**

[Total: 24]

3 Chlorine is manufactured by the electrolysis of sodium chloride solution. There are several different types of cell that can be used, including diaphragm and membrane cells.

A membrane cell with oxygen-depolarised cathodes, ODC, is a new development that is being trialled. The ODC cell differs from the others in that it does not produce hydrogen at the cathode.

The table below compares the three different types of cell.

		Diaphragm	**Membrane**	**Membrane with ODC**
Operating voltage (V)		2.9–3.5	3.0–3.6	Approx. 2
Relative energy consumption per tonne Cl_2	Electrolysis	2.7	2.6	1.8*
	Evaporation	0.6	0.2	0.2
	Total	3.3	2.8	2.0*
CO_2 emissions (tonnes per tonne Cl_2)		1.7	1.5	1.0

* estimated values

(a) Suggest **two** reasons why the new ODC cell is being classed as green technology when compared to the other types of cell.

....

....

.... **[2]**

(b) In all these cells, chlorine is produced at one electrode.

(i) Write the half-equation for the production of chlorine at this electrode in any of these cells.

$\rightarrow$

[2]

(ii) Write the electronic configuration, in terms of s and p sub-shells, for a chlorine **atom**.

.... **[1]**

(iii) Give **two** large scale uses for the chlorine that is formed.

....

....

....**[2]**

(iv) If an accident occurred causing a release of chlorine, people dealing with the incident would wear breathing apparatus.

Explain why this would be necessary.

....

.... **[2]**

(c) **Equations 3.1** and **3.2** show the processes that occur in an ODC cell at one electrode.

$O_2 + 4e^- \longrightarrow 2O^{2-}$ **equation 3.1**

$2O^{2-} + 2H_2O \longrightarrow 4OH^-$ **equation 3.2**

Write the overall half-equation for the reaction at this electrode.

→

[1]

(d) **Equation 3.3** represents the overall reaction that occurs in the membrane electrolysis cell. All three products have uses in industry.

$2NaCl(aq) + 2H_2O(l) \longrightarrow H_2(g) + Cl_2(g) + 2NaOH(aq)$ **equation 3.3**

(i) Calculate the volume of chlorine gas (in dm^3) that would be produced from 200 kg of dissolved sodium chloride.

Assume that 1 mole of gas occupies 24 dm^3 under the conditions of the experiment.

volume = ... dm^3 **[3]**

(ii) Give the atom economy for the reaction shown in **equation 3.3**.

.... **[1]**

(e) Sodium chloride can be produced in the laboratory by burning sodium in chlorine.

(i) In the reaction between sodium and chlorine, each sodium atom forms a sodium ion.

Write an equation representing the first ionisation enthalpy of sodium.

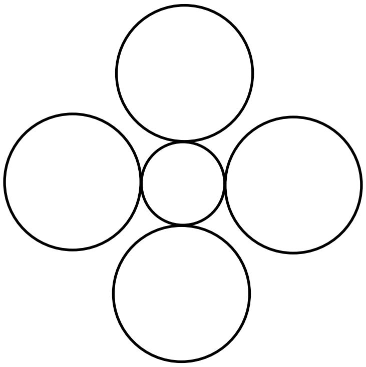
Include state symbols.

$\rightarrow$

[2]

(ii) The diagram below shows part of a layer of the sodium chloride lattice.

Label each type of particle and complete the diagram by drawing in enough particles to show the structure of the **layer** clearly.



[3]

[Total: 19]

4 Large quantities of propene, $CH_3CH{=}CH_2$, are manufactured every year. Most of this propene is used to make poly(propene), which is used to cover electrical wires.

(a) Draw the structure of **one** repeat unit of poly(propene).

[1]

(b) Suggest a property of poly(propene) that makes it suitable for the covering of electrical wires.

....

.... **[1]**

(c) Poly(propene) is an example of a thermoplastic polymer.

Explain what is meant by the term *thermoplastic*.

....

.... **[1]**

(d) Propene reacts with water, forming propan-1-ol as one of the products.

Propan-1-ol has a higher boiling point than propene.

Explain this difference in boiling points in terms of intermolecular bonding.

In this question, you should make it clear how the points you make are linked to one another.

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.... **[5]**

(e) A chemical company decided to make propan-1-ol from propene. The equation for the reaction is shown below.

$$CH_3CH{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2CH_2OH(g) \quad \Delta H = -37\ \mathrm{kJ\ mol^{-1}} \qquad \textbf{equation 4.1}$$

Describe and explain the effect, if any, on the equilibrium **yield** of propan-1-ol in each of these cases:

(i) increasing the temperature,

In your answer, you should use technical terms, spelled correctly.

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.... **[2]**

(ii) increasing the pressure.

....

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.... **[2]**

(f) **(i)** The temperature of the reaction mixture is increased.

Explain why the rate of the forward reaction in **equation 4.1** increases.

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.... **[3]**

(ii) What happens to the rate of the reverse reaction in **equation 4.1** when the temperature is increased?

....

.... **[1]**

[Total: 16]

5 This question is based on the Advance Notice article '***Atmospheric Nitrogen: Out of Thin Air***' that is provided as an insert to this paper.

(a) Explain what is meant by the term *radical*. Give an example of a radical from the article, other than the hydroxyl radical.

explanation: ....

....

example: ....

.... **[2]**

(b) One nitrogen-containing compound found in the atmosphere is N_2O, see Fig. 2 in the article.

(i) Draw a '*dot-and-cross*' diagram to represent the bonding in a molecule of N_2O.

Show outer electrons only.

[2]

(ii) Using your answer in **(i)**, describe and explain the shape of an N_2O molecule.

....

....

....

.... **[3]**

(c) Nitrogen is also present in the atmosphere in NH_4^+ and NO_2^-.

(i) The conversion of NH_4^+ to NO_2^- is classified as oxidation.

Calculate the oxidation states for the nitrogen in NH_4^+ and NO_2^-. Use these oxidation states to explain why this conversion is classified as oxidation.

oxidation state of N in NH_4^+..

oxidation state of N in NO_2^- ....

explanation: ....

....

.... **[3]**

(ii) Give the systematic name for NO_2^-.

.... **[1]**

(d) Some of the ammonia in the atmosphere comes from the decomposition of urea.

(i) Write an equation for the decomposition of urea, in the presence of water, to form ammonia and carbon dioxide.

$$\boxed{\quad\quad\quad\quad \rightarrow \quad\quad\quad\quad}$$

[1]

(ii) The concentration of ammonia in a sample of air is found to be 0.0010 ppm.

The concentration of nitrogen in the same sample is 78%.

How much more abundant is nitrogen than ammonia in this sample of air?

answer = ... times more abundant **[2]**

Question 5 continues on page 16

(e) Nitrous oxide, N_2O, is an important greenhouse gas.

Describe ways in which nitrous oxide is put into the atmosphere and ways in which it is removed from the atmosphere.

Include **one** chemical equation in your answer.

In your answer, you should make a clear link between the process you have described and the equation for the reaction.

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.... **[6]**

[Total: 20]

END OF QUESTION PAPER

For Question 5

Origin of the Earth’s atmosphere

adapted from ‘Origin of the Earth’s Atmosphere’ by Dr John Stimac (Eastern Illinois University)

Introduction

Early Earth would have been very different and inhospitable compared to the Earth today.

Most scientists think that the earliest atmosphere would have been completely different in composition from the one we have now, probably being composed mainly of hydrogen (H_2) and helium (He).

Cooling of the Earth could have happened as primordial heat dissipated into space. This would have resulted in the condensation of water (to form rain) and the subsequent accumulation of surface water.

Evolution of the atmosphere

Our atmosphere is the envelope of gases that surrounds the Earth. It provides a reservoir of some of the chemical compounds needed for living systems. The atmosphere has no outer boundary; it just fades into space. The dense part of the atmosphere (97% of its mass) lies within 30 km of the Earth’s surface (i.e. it is about the same thickness as the continental crust).

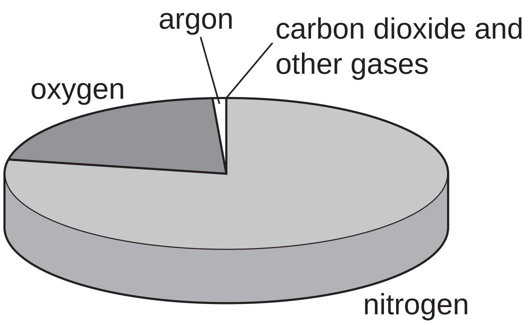

Fig. 1 Chemical composition of the Earth’s atmosphere today

The atmosphere’s chemical composition today is nitrogen, N_2 (~78%), oxygen, O_2 (~21%), argon, Ar (~1%), carbon dioxide, CO_2 (~0.03%), plus other gases, as shown in **Fig. 1** and **Table 1**.

constituent	percentage by volume	composition in parts per million (ppm)
Nitrogen (N_2)	78.084	
Oxygen (O_2)	20.948	
Argon (Ar)	0.934	
Carbon dioxide (CO_2)	0.0314	
Neon (Ne)		18.18
Helium (He)		5.24
Methane (CH_4)		2.00
Krypton (Kr)		1.14
Hydrogen (H_2)		0.50

Table 1 Principal gases in dry, unpolluted tropospheric air

(data from CRC Handbook of Chemistry and Physics, edited by David R. Lide, 1997)

Earth's first atmosphere

The Earth's first atmosphere probably had a composition of nearly all hydrogen and helium. These gases are relatively rare on Earth compared to other parts of the Universe and were probably lost to space early in Earth's history because Earth's gravity is not strong enough to hold lighter gases.

Today, Earth's core comprises a solid inner and liquid outer core. This is referred to as a differentiated core and creates Earth's magnetic field which allows heavier gases to be retained. Very early Earth probably did not have a differentiated core and so gases were lost.

Once the core differentiated, the heavier gases could be retained.

Addition of O_2 to the atmosphere

Today, the atmosphere is approximately 21% free oxygen. How did oxygen reach these levels in the atmosphere? To answer this question, we need to revisit the oxygen cycle:

- Processes causing oxygen production:
  - **photochemical dissociation** causing the break-up of water molecules by UV radiation. This produced oxygen levels at approximately 1−2% of current levels. At these levels O_3 (ozone) can form to shield the Earth's surface from UV radiation,
  - **photosynthesis** occurred in cyano-bacteria and eventually higher plants, using carbon dioxide, water and sunlight to produce organic compounds and oxygen, which supplied the rest of the O_2 to the atmosphere;
- Processes that consumed oxygen were:
  - **chemical weathering**, through the oxidation of surface materials (an early consumer),
  - **animal respiration** (which happened much later),
  - **burning of fossil fuels** (which started much, much later).

Throughout the Archean (before 2.5 billion years ago), there was little to no free oxygen in the atmosphere (<1% of present levels). What little was produced by cyanobacteria was probably consumed by the weathering process. Once rocks at the surface were sufficiently oxidised, more oxygen could remain free in the atmosphere.

During the Proterozoic (between around 540 million and 2.5 billion years ago), the amount of free O_2 in the atmosphere rose from 1 to 10%. Most of this was released by cyanobacteria, which increase in abundance in the fossil record about 2.3 billion years ago. Present levels of O_2 were probably not achieved until about 400 million years ago.

Evidence from the rock record

- Iron (Fe) is extremely reactive with oxygen. If we look at the oxidation state of Fe in the rock record, we can infer a great deal about atmospheric evolution;
- In Archean sediments we find the occurrence of minerals that only form in non-oxidising environments, *e.g.* Pyrite (Fools gold; FeS_2). These minerals are easily removed from rocks by oxidation under present atmospheric conditions;
- The presence of ***Banded Iron Formation (BIF)*** – Deep-water deposits in which layers of iron-rich minerals alternate with iron-poor layers, primarily chert. These iron minerals include iron oxide, iron carbonate, iron silicate and iron sulfide. BIFs are a major source of iron ore, because they contain magnetite (Fe_3O_4) that has a higher iron-to-oxygen ratio than hematite. These are common in rocks 2.0−2.8 billion years old, but do not form today;
- ***Red beds*** (continental siliciclastic deposits) are never found in rocks older than 2.3 billion years old, but are common during the Phanerozoic time (between now and around 540 million years ago). Red beds are red because of the highly oxidised mineral hematite (Fe_2O_3), which probably forms secondarily by oxidation of other iron minerals that have accumulated in the sediment.

The conclusion is that the amount of oxygen in the atmosphere has increased with time.

Atmospheric structure

Not only does the atmosphere have a relatively stable composition, but it also has a structure to it.

The Earth's outermost atmosphere, the part above a few hundred kilometres, is a region of extremely low density. Near sea level, an atom or molecule, on the average, undergoes about 7×10^9 collisions each second; near 600 km, this number is about one each minute!

Not only does the pressure change with altitude, but temperature does as well.

Originally, scientists thought that temperature decreased continuously with increasing height until reaching absolute zero (−273.15 °C). This decrease of temperature with increasing altitude is known as the environmental lapse rate and is approximately 6.5 °C per km. In **Fig. 2**, the environmental lapse rate can be seen graphically as the decrease in temperature with increasing height throughout the troposphere.

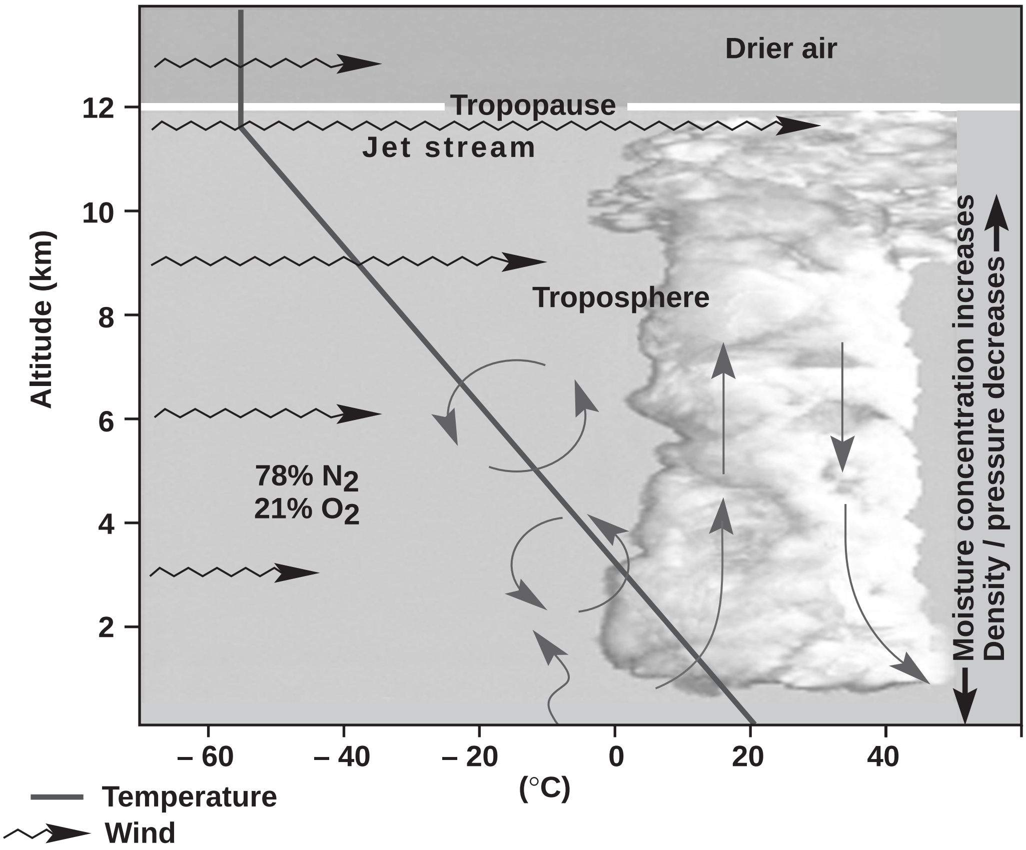

Fig. 2 Environmental lapse rate and the tropopause

Vertical structure of the atmosphere

After many balloon flights and temperature measurements, we know that temperature does not decrease continuously with increased height and the atmosphere can be divided into four regions, as shown in **Fig. 3**.

The bottom layer, where temperature decreases with altitude, is known as the troposphere (from the Greek for ‘turning layer’). The top of the troposphere is marked by the tropopause. This is the point at which the environmental lapse rate is no longer observed and is the first major break in the atmosphere.

Above the tropopause lies the stratosphere, which gets its name from the Greek meaning ‘stratified layer’. The layer is stratified with the denser, cooler air below the warmer, lighter air. This leads to an increase in temperature with height (see **Fig. 3**). The primary reason that there is a temperature increase with altitude is that most of the ozone is contained in the stratosphere. Ultraviolet light interacting with the ozone causes the temperature increase.

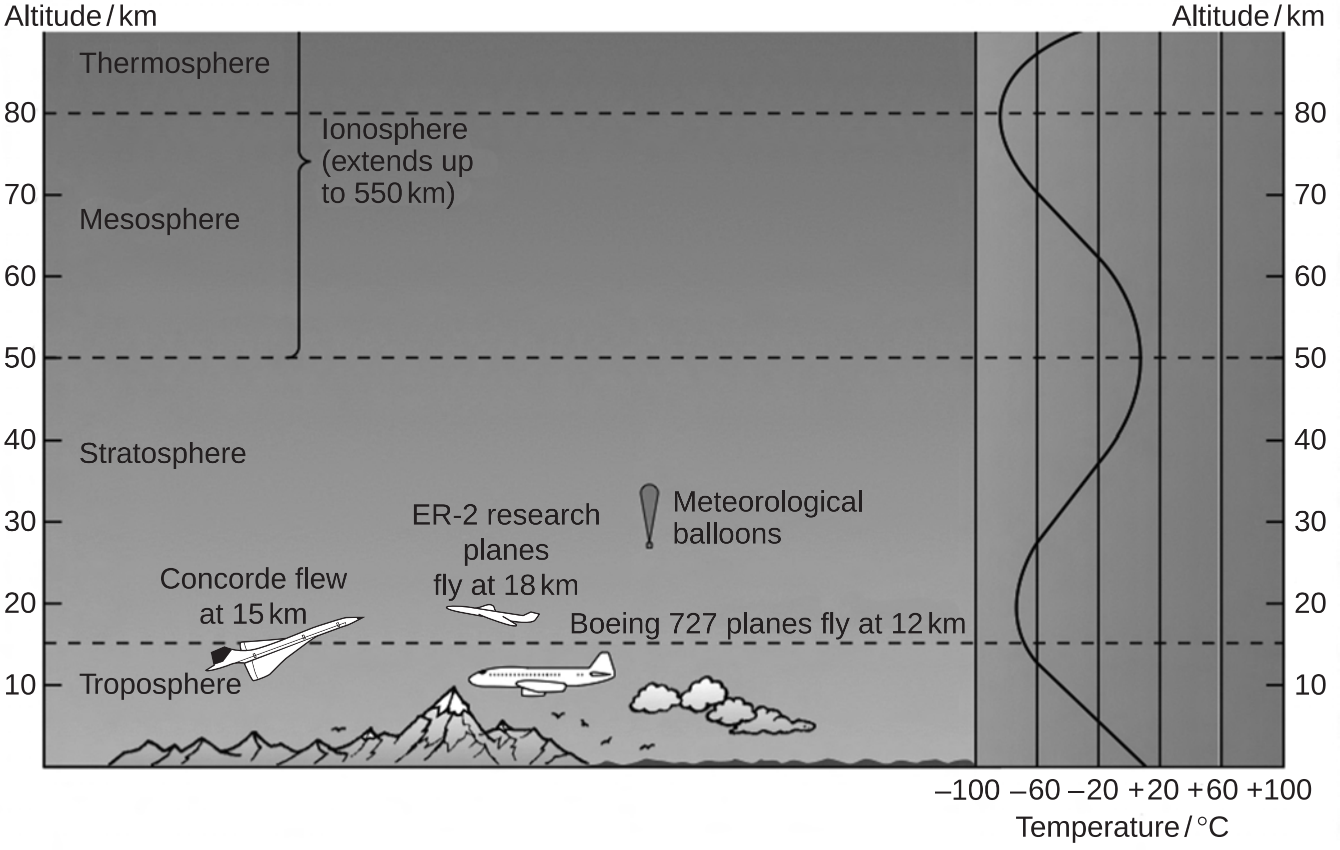

Fig. 3 Thermal structure of the atmosphere

END OF ADVANCE NOTICE ARTICLE