READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, highlighters, glue or correction fluid.
Write your name, Centre number and candidate number on the Answer Sheet in the spaces provided unless this has been done for you.

There are forty questions on this paper. Answer all questions. For each question there are four possible answers A, B, C and D.
Choose the one you consider correct and record your choice in soft pencil on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this booklet.
Section A

For each question there are four possible answers, A, B, C, and D. Choose the one you consider to be correct.

1 Use of the Data Booklet is relevant to this question.

What could be the proton number of an element that has three unpaired electrons in each of its atoms?

A 5  B 13  C 15  D 21

2 Use of the Data Booklet is relevant to this question.

The elements radon (Rn), francium (Fr) and radium (Ra) have consecutive proton numbers in the Periodic Table.

What is the order of their first ionisation energies?

<table>
<thead>
<tr>
<th></th>
<th>least endothermic</th>
<th>most endothermic</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Fr</td>
<td>Ra</td>
</tr>
<tr>
<td>B</td>
<td>Fr</td>
<td>Rn</td>
</tr>
<tr>
<td>C</td>
<td>Ra</td>
<td>Fr</td>
</tr>
<tr>
<td>D</td>
<td>Rn</td>
<td>Ra</td>
</tr>
</tbody>
</table>

3 Which gas closely approaches ideal behaviour at room temperature and pressure?

A ammonia

B carbon dioxide

C helium

D oxygen
Some bond energy values are listed below.

<table>
<thead>
<tr>
<th>bond</th>
<th>bond energy/kJ mol(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>C–H</td>
<td>410</td>
</tr>
<tr>
<td>C–Cl</td>
<td>340</td>
</tr>
<tr>
<td>Cl–Cl</td>
<td>244</td>
</tr>
<tr>
<td>Br–Br</td>
<td>193</td>
</tr>
</tbody>
</table>

These bond energy values relate to the following four reactions.

- P \( \text{Br}_2 \rightarrow 2\text{Br} \)
- Q \( 2\text{Cl} \rightarrow \text{Cl}_2 \)
- R \( \text{CH}_3 + \text{Cl} \rightarrow \text{CH}_3\text{Cl} \)
- S \( \text{CH}_4 \rightarrow \text{CH}_3 + \text{H} \)

What is the order of enthalpy changes of these reactions from most negative to most positive?

A  P \(\rightarrow\) Q \(\rightarrow\) R \(\rightarrow\) S
B  Q \(\rightarrow\) R \(\rightarrow\) S \(\rightarrow\) P
C  R \(\rightarrow\) Q \(\rightarrow\) P \(\rightarrow\) S
D  S \(\rightarrow\) P \(\rightarrow\) Q \(\rightarrow\) R

Given the following enthalpy changes,

- \( \text{I}_2(\text{g}) + 3\text{Cl}_2(\text{g}) \rightarrow 2\text{ICl}_3(\text{s}) \quad \Delta H^\circ = -214 \text{ kJ mol}^{-1} \)
- \( \text{I}_2(\text{s}) \rightarrow \text{I}_2(\text{g}) \quad \Delta H^\circ = +38 \text{ kJ mol}^{-1} \)

What is the standard enthalpy change of formation of iodine trichloride, \(\text{ICl}_3(\text{s})\)?

A  +176 kJ mol\(^{-1}\)
B  –88 kJ mol\(^{-1}\)
C  –176 kJ mol\(^{-1}\)
D  –214 kJ mol\(^{-1}\)

Ammonium nitrate, \(\text{NH}_4\text{NO}_3\), can decompose explosively when heated.

\[ \text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2\text{H}_2\text{O} \]

What are the changes in the oxidation numbers of the two nitrogen atoms in \(\text{NH}_4\text{NO}_3\) when this reaction proceeds?

A  \(-2, -4\) \quad B  \(+2, +6\) \quad C  \(+4, -6\) \quad D  \(+4, -4\)
7 The Haber process for the manufacture of ammonia is represented by the following equation.

\[ \text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1} \]

Which statement is correct about this reaction when the temperature is increased?

A Both forward and backward rates increase.
B The backward rate only increases.
C The forward rate only increases.
D There is no effect on the backward or forward rate.

8 Use of the Data Booklet is relevant to this question.

2.920 g of a Group II metal, \( X \), reacts with an excess of chlorine to form 5.287 g of a compound with formula \( XCl_2 \).

What is metal \( X \)?

A barium
B calcium
C magnesium
D strontium

9 Which mass of gas would occupy a volume of 3 dm\(^3\) at 25°C and 1 atmosphere pressure? [1 mol of gas occupies 24 dm\(^3\) at 25°C and 1 atmosphere pressure.]

A 3.2 g \( \text{O}_2 \) gas
B 5.6 g \( \text{N}_2 \) gas
C 8.0 g \( \text{SO}_2 \) gas
D 11.0 g \( \text{CO}_2 \) gas
10 The table gives the concentrations and pH values of the aqueous solutions of two compounds, X and Y. Either compound could be an acid or a base.

<table>
<thead>
<tr>
<th></th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>concentration</strong></td>
<td>2 mol dm(^{-3})</td>
<td>2 mol dm(^{-3})</td>
</tr>
<tr>
<td><strong>pH</strong></td>
<td>6</td>
<td>9</td>
</tr>
</tbody>
</table>

Student P concluded that X is a strong acid.

Student Q concluded that the extent of dissociation is lower in X(aq) than in Y(aq).

Which of the students are correct?

A both P and Q  
B neither P nor Q  
C P only  
D Q only

11 Swimming pool water can be kept free of harmful bacteria by adding aqueous sodium chlorate(I), NaOCl. This reacts with water to produce HOCl molecules which kill bacteria.

\[
\text{OC}^\text{\textnormal{I}}^- (\text{aq}) + \text{H}_2\text{O} \rightleftharpoons \text{OH}^- (\text{aq}) + \text{HOCl}(\text{aq})
\]

In bright sunshine, the OC\(^{\text{\textnormal{I}}}^-\) ion is broken down by ultra-violet light.

\[
\text{OC}^\text{\textnormal{I}}^- (\text{aq}) + \text{uv light} \rightarrow \text{Cl}^- (\text{aq}) + \frac{1}{2}\text{O}_2(\text{g})
\]

Which method would maintain the highest concentration of HOCl(aq)?

A acidify the pool water  
B add a solution of chloride ions  
C add a solution of hydroxide ions  
D bubble air through the water
12 Na₂S₂O₃ reacts with dilute HCl to give a pale yellow precipitate. If 1 cm³ of 0.1 mol dm⁻³ HCl is added to 10 cm³ of 0.02 mol dm⁻³ Na₂S₂O₃ the precipitate forms slowly.

If the experiment is repeated with 1 cm³ of 0.1 mol dm⁻³ HCl and 10 cm³ of 0.05 mol dm⁻³ Na₂S₂O₃ the precipitate forms more quickly.

Why is this?

A The activation energy of the reaction is lower when 0.05 mol dm⁻³ Na₂S₂O₃ is used.
B The reaction proceeds by a different pathway when 0.05 mol dm⁻³ Na₂S₂O₃ is used.
C The collisions between reactant particles are more violent when 0.05 mol dm⁻³ Na₂S₂O₃ is used.
D The reactant particles collide more frequently when 0.05 mol dm⁻³ Na₂S₂O₃ is used.

13 How does concentrated sulfuric acid behave when it reacts with sodium chloride?

A as an acid only
B as an acid and oxidising agent
C as an oxidising agent only
D as a reducing agent only

14 X is a salt of one of the halogens chlorine, bromine, iodine, or astatine (proton number 85).

The reaction scheme shows a series of reactions using a solution of X as the starting reagent.

[X] \( \xrightarrow{HNO₃(aq)} \text{a precipitate} \xrightarrow{\text{an excess of} \ AgNO₃(aq)} \text{a colourless solution} \xrightarrow{\text{an excess of} \ dilute \ NH₃(aq)} \text{a precipitate} \)

What could X be?

A sodium chloride
B sodium bromide
C potassium iodide
D potassium astatide
15 The percentage of ammonia obtainable, if equilibrium were established during the Haber process, is plotted against the operating pressure for two temperatures, 400°C and 500°C.

Which diagram correctly represents the two graphs?

A

\[
\begin{array}{c}
\text{% NH}_3 \text{ at equilibrium} \\
\text{pressure/10}^3 \text{kPa}
\end{array}
\]

B

\[
\begin{array}{c}
\text{% NH}_3 \text{ at equilibrium} \\
\text{pressure/10}^3 \text{kPa}
\end{array}
\]

C

\[
\begin{array}{c}
\text{% NH}_3 \text{ at equilibrium} \\
\text{pressure/10}^3 \text{kPa}
\end{array}
\]

D

\[
\begin{array}{c}
\text{% NH}_3 \text{ at equilibrium} \\
\text{pressure/10}^3 \text{kPa}
\end{array}
\]

16 Consecutive elements X, Y, Z are in the third period of the Periodic Table. Element Y has the highest first ionisation energy and the lowest melting point.

What could be the identities of X, Y and Z?

A aluminium, silicon, phosphorus

B magnesium, aluminium, silicon

C silicon, phosphorus, sulfur

D sodium, magnesium, aluminium

17 Which property of Group II elements (beryllium to barium) decreases with increasing atomic number?

A reactivity with water

B second ionisation energy

C solubility of hydroxides

D stability of the carbonates
18 Which element of the third period requires the least number of moles of oxygen for the complete combustion of 1 mol of the element?

A aluminium
B magnesium
C phosphorus
D sodium

19 Two properties of non-metallic elements and their atoms are as follows.

property 1 has an oxide that can form a strong acid in water
property 2 has no paired 3p electrons

Which properties do phosphorus and sulfur have?

<table>
<thead>
<tr>
<th></th>
<th>phosphorus</th>
<th>sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>1 and 2</td>
<td>1 only</td>
</tr>
<tr>
<td>B</td>
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<td>1 and 2</td>
</tr>
<tr>
<td>C</td>
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<td>1 and 2</td>
</tr>
<tr>
<td>D</td>
<td>2 only</td>
<td>1 only</td>
</tr>
</tbody>
</table>

20 When gaseous chemicals are transported by road or by rail they are classified as follows.

flammable non-flammable poisonous

Which commonly transported gas is non-flammable?

A butane
B hydrogen
C oxygen
D propene
21 When heated with chlorine, the hydrocarbon 2,2-dimethylbutane undergoes free radical substitution.

In a propagation step the free radical \( X^* \) is formed.

\[
\begin{align*}
&\text{CH}_3 \\
&\text{CH}_3\text{CH}_2\text{C}-\text{CH}_3 + \text{Cl}^* \rightarrow X^* + \text{HCl}
\end{align*}
\]

How many different forms of \( X^* \) are possible?

A 1  B 2  C 3  D 4

22 What will react differently with the two isomeric alcohols, \((\text{CH}_3)_3\text{CCH}_2\text{OH}\) and \((\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{OH}\)?

A acidified aqueous potassium manganate(VII)
B concentrated sulfuric acid
C phosphorus pentachloride
D sodium

23 Which reagent will give similar results with both butanone and butanal?

A acidified aqueous potassium dichromate(VI)
B an alkaline solution containing complexed Cu\(^{2+}\) ions (Fehling’s solution)
C an aqueous solution containing \([\text{Ag(NH}_3\text{)}_2]^+\) (Tollens’ reagent)
D 2,4-dinitrophenylhydrazine reagent

24 What is formed when propanone is refluxed with a solution of \( \text{NaBH}_4 \)?

A propanal
B propan-1-ol
C propan-2-ol
D propane

25 Which compound is a product of the hydrolysis of \( \text{CH}_3\text{CO}_2\text{C}_3\text{H}_7 \) by boiling aqueous sodium hydroxide?

A \( \text{CH}_3\text{OH} \)  B \( \text{C}_3\text{H}_7\text{OH} \)  C \( \text{C}_3\text{H}_7\text{CO}_2\text{H} \)  D \( \text{C}_3\text{H}_7\text{CO}_2\text{Na}^- \)
26 In many countries plastic waste is collected separately and sorted. Some of this is incinerated to provide heat for power stations.

Why is PVC, polyvinylchloride, removed from any waste that is to be incinerated?
A It destroys the ozone layer.
B It does not burn easily.
C It is easily biodegradable.
D Its combustion products are harmful.

27 Polymerisation of 1,1-dichloroethene produces a dense, high melting point substance that does not allow gases to pass through. It is used as cling wrapping.

Which sequence appears in a short length of the polymer chain?
A \( \text{CH}_2\text{CCl}_2\text{CH}_2\text{CCl}_2\text{CH}_2\text{CCl}_2 \)
B \( \text{C}\text{HCCHCCHClCHClCHCl} \)
C \( \text{CCl}_2\text{CCl}_2\text{CCl}_2\text{CCl}_2\text{CCl}_2 \)
D \( \text{CH}_2\text{CCl}_2\text{CHClCHClCH}_2\text{CCl}_2 \)

28 When an isomer Y of molecular formula \( \text{C}_4\text{H}_9\text{Br} \) undergoes hydrolysis in aqueous alkali to form an alcohol \( \text{C}_4\text{H}_9\text{OH} \), the rate of reaction is found to be unaffected by changes in the concentration of \( \text{OH}^- \) ions present.

Which is the most likely molecular structure of Y?
A \( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} \)
B \( \text{CH}_3\text{CH}_2\text{CHBrCH}_3 \)
C \( (\text{CH}_3)_2\text{CHCH}_2\text{Br} \)
D \( (\text{CH}_3)_3\text{CBr} \)

29 Which isomer of \( \text{C}_4\text{H}_{10}\text{O} \) forms three alkenes on dehydration?
A butan-1-ol
B butan-2-ol
C 2-methylpropan-1-ol
D 2-methylpropan-2-ol
30. Which compound exhibits both *cis-trans* and optical isomerism?

A. \( \text{CH}_3\text{CH} = \text{CHCH}_2\text{CH}_3 \)
B. \( \text{CH}_3\text{CHBrCH} = \text{CH}_2 \)
C. \( \text{CH}_3\text{CBr} = \text{CBrCH}_3 \)
D. \( \text{CH}_3\text{CH}_2\text{CHBrCH} = \text{CHBr} \)
Section B

For each of the questions in this section, one or more of the three numbered statements 1 to 3 may be correct.

Decide whether each of the statements is or is not correct (you may find it helpful to put a tick against the statements that you consider to be correct).

The responses A to D should be selected on the basis of

<table>
<thead>
<tr>
<th></th>
<th>A</th>
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<th>C</th>
<th>D</th>
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</table>

No other combination of statements is used as a correct response.

31 Which diagrams represent part of a giant molecular structure?

32 Which reactions are redox reactions?

1 \( \text{CaBr}_2 + 2\text{H}_2\text{SO}_4 \rightarrow \text{CaSO}_4 + \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O} \)

2 \( \text{CaBr}_2 + 2\text{H}_3\text{PO}_4 \rightarrow \text{Ca(H}_2\text{PO}_4)_2 + 2\text{HBr} \)

3 \( \text{CaBr}_2 + 2\text{AgNO}_3 \rightarrow \text{Ca(NO}_3)_2 + 2\text{AgBr} \)

33 Sodium hydrosulfide, \( \text{NaSH} \), is used to remove hair from animal hides.

Which statements about the \( \text{SH}^- \) ion are correct?

1 It contains 18 electrons.

2 Three lone pairs of electrons surround the sulfur atom.

3 Sulfur has an oxidation state of +2.
34 When organic refuse decomposes in water carboxylic acids are formed. The water becomes acidic and aquatic life is destroyed.

Which additives are suitable to remove this acid pollution?

1 calcium carbonate
2 calcium hydroxide
3 potassium nitrate

35 In a car engine, non-metallic element X forms a pollutant oxide Y.

Further oxidation of Y to Z occurs in the atmosphere. In this further oxidation, 1 mol of Y reacts with $\frac{1}{2}$ mol of gaseous oxygen.

What can X be?

1 carbon
2 nitrogen
3 sulfur

36 Sulfur dioxide and sulfites are used in food preservation.

Why are they used for this purpose?

1 They are reducing agents so retard the oxidation of food.
2 They inhibit the growth of aerobic bacteria.
3 They react with NO$_2$(g) converting it to NO(g).

37 Propanoic acid occurs naturally as a result of the bacterial fermentation of milk, and is partly responsible for the flavour of Swiss cheese.

Which starting materials could be used to synthesise propanoic acid?

1 CH$_3$CH$_2$CH$_2$OH
2 CH$_3$CH$_2$CN
3 CH$_3$CH$_2$CHO
The responses A to D should be selected on the basis of

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No other combination of statements is used as a correct response.

38 Which structural formulae represent 2,2-dimethylpentane?
1 \((\text{CH}_3)_2\text{CHCH}_2\text{CH(\text{CH}_3)_2}\)
2 \((\text{CH}_3)_3\text{CCH}_2\text{CH}_3\)
3 \(\text{CH}_3\text{CH}_2\text{CH}_3\text{C(\\text{CH}_3)_3}\)

39 Which reactions are examples of nucleophilic substitution?
1 \(\text{CH}_3\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{Br}^-\)
2 \(\text{CH}_3\text{I} + \text{H}_2\text{O} \underset{\text{H}^+}{\rightarrow} \text{CH}_3\text{OH} + \text{HI}\)
3 \(\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl} + \text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 + \text{HCl}\)

40 The diagram shows some laboratory apparatus.

Which preparations could this apparatus be used for?
1 bromoethane, from ethanol, sodium bromide and concentrated sulfuric acid
2 ethanal, from ethanol, sodium dichromate(VI) and sulfuric acid
3 1,2-dibromoethane, from bromine and ethene