PHYSICAL SCIENCES: PAPER II

MARKING GUIDELINES

Time: 3 hours 200 marks

These marking guidelines are prepared for use by examiners and sub-examiners, all of whom are required to attend a standardisation meeting to ensure that the guidelines are consistently interpreted and applied in the marking of candidates' scripts.

The IEB will not enter into any discussions or correspondence about any marking guidelines. It is acknowledged that there may be different views about some matters of emphasis or detail in the guidelines. It is also recognised that, without the benefit of attendance at a standardisation meeting, there may be different interpretations of the application of the marking guidelines.
QUESTION 1  MULTIPLE-CHOICE

1.1  D
1.2  B
1.3  C
1.4  D
1.5  B
1.6  A
1.7  C
1.8  A
1.9  D
1.10 B

[10 × 2 = 20]

QUESTION 2  CHEMICAL BONDING

2.1 2.1.1 It is a bond occurring between atoms within molecules. (1)
2.1.2 Polar/covalent/bond. (2)
2.1.3 A (weak) force of attraction between molecules or between atoms of noble gases. (2)
2.1.4 Hydrogen bond (Hydrogen bonding intermolecular force). (1)
2.1.5 It is a (small) atom with a high electronegativity and it has at least one lone pair of electrons. (2)
2.1.6 $\delta^+$ (allow positive; +; $\alpha^+$) (1)

2.2 2.2.1 A transfer of electrons and subsequent electrostatic attraction. (2)
2.2.2* • Large number of STRONG electrostatic forces (ionic bonds, coulombic forces) of attraction between ions in giant network structure. (3)
• Large amount of energy required to break/overcome these forces.

2.2.3 Ion-dipole force (1)
2.2.4 Sodium ion (Na$^+$). The water molecules are orientated in such a way that the (slightly) negative oxygen atoms ($\delta^-$) are closest to the positive ion. (2)

C$\text{F}^-$ The water molecules are orientated in such a way that the (slightly) positive oxygen atoms are closest to the positive ion.
If 2.1.6 is wrong no mark is given in 2.2.4 for either Na$^+$ or C$\text{F}^-$ without justification.

2.2.5* The electrostatic forces (ionic bonds) holding the ions in the crystal lattice are much stronger than the ion-dipole forces between the ions and the water molecules. Large numbers of water molecules need to surround each ion in order to overcome the strong electrostatic forces and "pull" the ion out of the lattice. (3)

* Penalise wrong use of terminology (e.g. atoms instead of ions) once in total in Question 2.2.2 and Question 2.2.5

[20]
QUESTION 3 ENERGY CHANGE AND REACTION RATES

3.1 (Sulphur) is insoluble/solid/precipitate/murky/opaque/turbid and blocks the light. Don't give a mark for saying there is a decrease in light intensity as that is stated in the question. (2)

3.2

3.2.1 label concentration mol•dm$^{-3}$ or M

3.2.2 Scale

- 180
- 160
- 140
- 120
- 100
- 80
- 60
- 40
- 20
- 0

3.2.3 plot point

3.2.4 best-fit line

3.2.2 Scale

- If scale is wrong no marks can be awarded for plotting points.
- No marks for best-fit line which is 'dot-to-dot/line segments' or 'sketched/hairy' but a wobbly curve is acceptable.

3.3 Time is the dependent variable OR time depends on concentration. No marks for stating 'time is measured'. (1)

3.4 Straight line, which passes through the origin (0). Correct sketch of graph (one mark only). Ignore reference to positive or negative slope. (2)

3.5 The reaction rate increases as there are more particles (of Na$_2$S$_2$O$_3$) per unit volume therefore more effective (correct orientation and sufficient activation energy) collisions per unit time. (3)
3.6 Place the flask containing the sodium thiosulphate solution on top of a large black cross drawn on a piece of white paper. Carry out step 2 of the original method but stop the watch when the cross is no longer visible when viewed through the solution from above. OR Measure change in mass/pressure/volume of gas collected/pH with time.

3.7 3.7.1 \[ n = c \times V = 0,2 \times 0,1 \text{ (conversion)} = 0,02 \text{ mol of HCl} \]

3.7.2 mol ratio HCl : S
\[
\begin{align*}
2 : 1 \\
0,02 : 0,01
\end{align*}
\]

\[
\text{m} = n \times M = 0,01 \times (32) = 0,32 \text{ g}
\]

\[
\% \text{ yield} = \frac{0,18}{0,32} \times 100 \text{ (method)} = 56,25\%
\]

\[
\text{IF one error only (eg wrong molar mass of S or wrong ratio) gets 3/5}
\]

\[
\text{OR 3.7.1*} \quad n_{\text{Sulphur}} = \frac{m}{M} = \frac{0,18}{32} = 0,005625 \text{ mol}
\]

\[
\text{mol ratio HCl : S} \quad 2 : 1
\]

\[
0,01 \text{ mol (2d.p.)} \quad 0,01125 : 0,005625
\]

\[
\text{OR 3.7.2* If do alternative given above then}
\]

\[
\frac{n}{c \times V} = 0,2 \times 0,1 \text{ (conversion)} = 0,02 \text{ mol of HCl}
\]

\[
\% \text{ yield} = \frac{0,01125}{0,02} \times 100 = 56,25\%
\]

\[
\text{OR n} = \frac{m}{M} = 0,18/32 = 0,005625 \text{ mol of S}
\]

\[
\% \text{ yield} = \frac{0,005625}{0,01} \times 100 \text{ (method)} = 56,25\%
\]

\[
\text{QUESTION 4 CHEMICAL EQUILIBRIUM}
\]

4.1 As \( \text{A}_2\text{B} \) decomposes in the forward reaction, the concentration of \( \text{A}_2 \) and \( \text{B}_2 \) (or product) increases OR more particles of \( \text{A}_2 \)and \( \text{B}_2 \).

4.2 4.2.1 There has been an increase in concentration (or pressure) of both reactants and products.

4.2.2 Reverse

4.2.3 The reverse reaction is favoured since it leads to the formation of fewer moles of gas, which relieves the stress of high pressure (or lowers the pressure). (NO c.o.e. from 4.2.2)

4.3 Exothermic.
- Stress: Decrease in temperature.
- Response: Reverse reaction rate decreases more than forward reaction rate, therefore forward reaction favoured.
- Reason: Forward reaction produces heat (exothermic) in order to relieve the stress (raise the temperature).

4.4 A catalyst is added.

4.5 No change in \([\text{A}_2\text{B}]\). The rates of BOTH forward and reverse reactions have increased. EQUALLY or whilst remaining in equilibrium OR \( \text{A}_2\text{B} \) being broken down and produced at the same rate.

4.6 4.6.1 No effect.

4.6.2 Increases.

Must be consistent with 4.3 If state ENDO in 4.3 then must state decrease in 4.6.2
4.7 4.7.1 \[ V = \frac{n}{c} = \frac{3.6}{1.2} = 3 \text{ dm}^3 \] (2)

4.7.2 \[ K_c = \frac{[A_2]^2[B_2]}{[A_2B]^2} \] (2)

4.7.3 \[ [A_2B] = \frac{n}{V} = \frac{(5.1 - 3.6)}{3} \text{ method} \] or \[ [B_2] = \frac{n}{V} = \frac{1.8}{3} \text{ volume} \]

\[ 0.5 \text{ mol} \cdot \text{dm}^{-3} \div \text{volume} = 0.6 \text{ mol} \cdot \text{dm}^{-3} \]

**OR TABLE**

<table>
<thead>
<tr>
<th>MOLE table</th>
<th>(2A_2B(g))</th>
<th>(\leftrightarrow)</th>
<th>(2A_2(g))</th>
<th>+</th>
<th>(B_2(g))</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Mole ratio</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moles at start</td>
<td>5.1</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*Moles used/formed</td>
<td>3.6</td>
<td>3.6</td>
<td>1.8</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Moles at equilibrium</td>
<td>(5.1 - 3.6) = 1.5</td>
<td>3.6</td>
<td>1.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conc. at equilibrium (mol \cdot \text{dm}^{-3})</td>
<td>(1.5/3) = 0.5</td>
<td>1.2</td>
<td>1.8/3 = 0.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CONC table**

| *Mole ratio | 2 | 1 |
| Conc at start | 5.1/3 = 1.7 | 0 | 0 |
| *Conc change | 1.2 | 1.2 | 0.6 |
| Conc. at equilibrium (mol \cdot \text{dm}^{-3}) | (1.7 - 1.2) = 0.5 | 1.2 | 0.6 |

\[ K_c = \frac{[A_2]^2[B_2]}{[A_2B]^2} \text{ c.o.e.} \]

\[ = \frac{1.2^2 \times 0.6}{0.5^2} \text{ subst} \]

\[ = 3.46 \] (6)

**QUESTION 5** QUANTITATIVE CHEMISTRY AND ACIDS AND BASES

5.1 5.1.1 A solution of known concentration. (1)

5.1.2 Error & correction (any TWO of the following)

- Use of tap water. She should have used distilled water.
- Use of a beaker. She should have used a volumetric flask.
- Use of a glass rod to stir (as could transfer solute to rod). Mix by shaking the solution (in a sealed volumetric flask).
- She did not weigh the filter paper before and after transferring the solute to the beaker in order to ascertain (by subtraction) exactly how much solute was transferred. She should have done this (implied).
• She added the solute to 250 cm\(^3\) of water, which would have resulted in a greater total volume than 250 cm\(^3\). She should have added water to the solute to make up the total volume to 250 cm\(^3\).

5.1.3 sodium carbonate (Na\(_2\)CO\(_3\))

5.2

5.2.1 It is the point where an acid and base have reacted, so neither is in excess OR where equivalent (NOT same or equal) number of moles of acid and base have reacted.

5.2.2 Colour: Orange since more HIn is formed.
Stress: Increase [H\(_3\)O\(^+\)]
Response: Favour reverse reaction
Reason: Reverse reaction uses up H\(_3\)O\(^+\) or decreases [H\(_3\)O\(^+\)] therefore relieves stress.

5.3

5.3.1 \( n = \frac{V}{V_m} \)

\[ = 0,56 \div 22,4 \]

\[ = 0,025 \text{ mol of CO}_2 \text{ (OR 0,03 mol to 2 dp)} \] (2)

5.3.2 Mol ratio

\[
\begin{align*}
\text{HCl : CO}_2 & \\
2 : 1 & \\
0,05 : 0,025 & \text{ (OR 0,06 : 0,03)}
\end{align*}
\]

\[ V = \frac{n}{c} \]

\[ = \frac{0,05}{0,25} \quad \frac{0,06}{0,25} \]

\[ V = 0,2 \text{ dm}^3 \text{ of HCl} \quad = 0,24 \text{ dm}^3 \] (3)

5.4

5.4.1 \( \text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{H}_3\text{O}^+ + \text{CH}_3\text{COO}^- \) Don't penalise single arrow.
Reactants/Products.

5.4.2 GREATER THAN
Nitric acid is a stronger acid than ethanoic acid therefore it will ionise more/produce more ions/donates H\(^+\) more readily OR stronger acids have higher K\(_a\) values.

5.4.3 Nitric acid (c.o.e.) ( Allow ethanoic acid if they have identified it as the stronger acid in Question 5.4.2.)
It would have a higher concentration of ions (more ions) as it is a stronger acid.

5.4.4 Ethanoic acid ( Allow HNO\(_3\) if c.o.e. from Question 5.4.2.)
It is a weaker acid, therefore it would have a lower concentration of H\(_3\)O\(^+\) ions.

\[ K_w = [\text{H}_3\text{O}^+]\cdot[\text{OH}^-] = \text{constant OR [OH]}^- \text{ inversely proportional to [H}_3\text{O}^+\] \therefore \text{ if [H}_3\text{O}^+\) is lower, then [OH}^-\) must be higher. (3)
5.5 5.5.1 A salt is a substance in which the hydrogen of an acid has been replaced by a cation.

5.5.2 pH=7,1 – 11 It is a weak base/basic salt/salt of a strong base and a weak acid as it causes an increase in [OH⁻].

5.5.3 \[2\text{CH}_3\text{COOH} + \text{Na}_2\text{O} \rightarrow 2\text{CH}_3\text{COONa} + \text{H}_2\text{O}\] Reactants/Products/Balanced

**QUESTION 6 GALVANIC CELLS**

6.1 If identify Pb as cathode then coe for rest of diagram, Cu(NO₃)₂ as electrolyte in anode half-cell and electron from Cu to Pb

6.2 Pb(s)|Pb²⁺ (aq, 1 mol ⋅ dm⁻³)||Cu²⁺ (aq, 1 mol ⋅ dm⁻³)|Cu(s) at 25º C Anode/Salt bridge/Cathode/Standard conditions

6.3 \(E^\circ\) cell = \(E^\circ\) cathode – \(E^\circ\) anode

\[= 0,34 – (-0,13) \]

\[= 0,47 \text{ V}\]

6.4 6.4.1 Completes circuit/allows ions through maintains electrical neutrality/neutralises electrolyte/acts as an ion pump.

6.4.2 As a result of *oxidation of the lead anode* the *concentration of positive lead ions* (cations) in the lead half-cell *increases* therefore the negative iodide ions move into the lead half-cell in order to maintain electrical neutrality (maintain balance between positive and negative ions).

6.4.3 *Increases* emf.

6.5 6.5.1 Increases

6.5.2 No effect
QUESTION 7  ELECTROLYTIC CELLS

7.1 Electrical energy to chemical (potential) energy.  

7.2 \[
\text{Al}^{3+} + 3e^- \rightarrow \text{Al} \quad (-1 \text{ per error})
\]

7.3 \[
2\text{O}^{2-} \rightarrow \text{O}_2 + 4e^- \quad (-1 \text{ per error})
\]
\[
\text{C} + 2\text{O}^{2-} \rightarrow \text{CO}_2 + 4e^- \quad (-1 \text{ per error})
\]

7.4 The oxygen gas produced at the anode reacts with the graphite (carbon) to form carbon dioxide.
\[
\text{C} + \text{O}_2 \rightarrow \text{CO}_2 \quad \text{Reactants/Product}
\]
\[
2\text{Al}_2\text{O}_3 + 3\text{C} \rightarrow 3\text{CO}_2 + 4\text{Al}
\]

7.5 Less coal is burnt to produce electricity therefore fewer \(\text{CO}_2\) (greenhouse gas) emissions OR conserving non-renewable fossil fuel OR less poisonous gas emissions (from burning coal to make electricity). (ONE reason only which \textit{links to the environment}). Do NOT accept reduces electricity/energy consumption without a link to the environment.  

7.6 Cryolite is \textit{poisonous} or toxic fluoride (PFC) emissions (ONE reason only)  
Cryolite is mined which damages environment.

7.7 \(\text{Al}^{3+}\) ions are a \textit{weaker oxidising agent} (have a more negative \(E^0\)) than \(\text{H}_2\text{O}\) molecules, therefore \(\text{H}_2\text{O}\) will be reduced at the cathode in preference to \(\text{Al}^{3+}\) ions.
\[
2\text{H}_2\text{O} + 2e^- \rightarrow \text{H}_2 + 2\text{OH}^- \quad (-1 \text{ per error})
\]

QUESTION 8  ORGANIC

8.1 8.1.1 A compound containing only carbon and hydrogen atoms in which there is at least one \textit{double and/or triple bond} between carbon atoms.  

8.1.2 2-methylbut-2-ene  
\textit{Mark allocation:} 2-methyl but -2- ene  
The first 2- is redundant and need not be shown.  
-1 if formatting error (gap between methyl and but- or no hyphens))

8.2 8.2.1 An atom or group of atoms that forms the centre of chemical activity in the molecule OR an atom or group of atoms that gives a compound its physical and chemical properties.  

8.2.2  
\[\text{H} - \text{C} - \text{C} - \text{C} - \text{O} - \text{H}\]  
3 C’s  
Structure correct  
Functional group correctly identified

If give semi-structural or condensed structural formula –1 per question.

If give molecular formula then give 0

8.2.3  
\[\text{H} - \text{C} - \text{C} - \text{O} - \text{C} - \text{H} - \text{H}\]  
Ethyl & methyl correct  

\[14\]
8.2.4 They have the **same molecular formula** (but different structural formulae) and **different functional groups/homologous series**.  

8.2.5 Methanol

8.2.6 Ethyl methanoate

8.2.7 Propanoic acid

8.2.8 • Propanoic acid has **hydrogen bonds** between molecules.  
• Methyl ethanoate has **dipole-dipole forces** between molecules.  
• Hydrogen bonds are **stronger** than dipole-dipole forces.  
• **More energy** needed to overcome the stronger intermolecular forces.  
  Do **NOT** give final mark if they say more energy … to break **bonds**.

8.3 8.3.1 (a) CH₃CH₃ or CH₃-CH₃ 2C 6H  
(b) CH₃CH₂OH CH₃CH₂ OH

8.3.2 (a) chloroethane chloro ethane  
(b) ethene eth ene

8.3.3 haloalkane (alkyl halide)

8.3.4 alkene

8.3.5 (a) substitution (free radical substitution/halogenation/chlorination)  
(b) substitution (hydrolysis)  
(c) elimination (dehydration)  
(d) addition (hydrogenation)  
(e) combustion (redox/oxidation)

**Wrong format of formula** -1  
**Gap between CH₃ and CH₃** -1

(a) and (b) penalise each error once only  
Don't penalise gap in name if already penalised in 8.1.2 (c.o.e.)
Don't penalise redundancy unless wrong eg take off a mark for 2-chloroethane and eth-2-ene

Mark first answer if more than one is given.

Total: 200 marks