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St Alban's College: GRADE 12
Physical Science: Paper 2 (Chemistry)
23 September 2022
Marking Guidelines

Question 1: Multiple Choice**[20]**

Answer these questions on the multiple-choice answer grid below. Make a clear cross (X) in the box corresponding to the letter that you consider to be correct. Every question has only one correct answer.

- 1.1C Use the formulae of the compounds to see how many nitrate ions are in each compound
- 1.2A Use the electronegativity values on the PT to find which bonds have the greatest difference in electronegativity between the atoms.
- 1.3B For an endothermic reaction, E_{in} (to break bonds) $>$ E_{out} (when bonds form)
- 1.4B
- | | | | | | |
|-------------|-------|---|----|----------------------|-----------------|
| | D | + | 2E | $\rightleftharpoons$ | DE ₂ |
| Initial | 2 | | 2 | | 0 |
| Max change | -1 | | -2 | | +1 |
| Equilibrium | min 1 | | | | max 1 |
- 1.5B A conjugate acid-base pair differs by the gain or loss of **one H⁺**.
- 1.6B Larger surface area electrodes and anything that lowers the internal resistance will increase the current.
- 1.7C SHE always on LHS in cell notation. Written as anode $\therefore$ oxidation $\therefore$ H₂ to H⁺
- 1.8D In electroplating, the object to be plated must be connected to the negative terminal (i.e. it is the cathode). The cations in solution are attracted to it and undergo reduction to form metal atoms.
- 1.9D The more branched the isomer, the more compact the molecule, the lower the bp (reason D).
- 1.10C Know that addition results in a single product, while substitution results in two products $\therefore$ Q unsaturated. Addition of Br₂ will result in a product with 2 Br atoms. All hydrocarbons undergo combustion.

Question 2:**[14]**

Neon is an unreactive noble gas used in lights since 1912.

- 2.1 Define an *intramolecular bond*. (2)

A bond that occurs between atoms within molecules. ✓✓

- 2.2 Why do noble gases not form any intramolecular bonds? (2)

Noble gases have a full valence electron structure ✓
 $\therefore$ no sharing or transfer of electrons ✓

- 2.3 London forces are present in all the noble gases. Explain how these forces originate in neon. (3)

**Electrons are constantly moving and temporary dipoles are created when electrons are unevenly distributed ✓
which induces dipoles in neighbouring atoms ✓
Attraction between the oppositely charged (temporary) dipoles ✓**

- 2.4 The intermolecular forces present in chlorine gas are also London forces but chlorine gas has a higher boiling point than neon. Explain the difference between the boiling point of chlorine and neon. (4)

**Chlorine has more electrons than neon ✓
More and stronger induced/temporary dipoles can form ✓
Stronger (London) intermolecular forces ✓
More energy is needed to overcome these stronger forces in chlorine ✓ giving it the higher boiling point**

- 2.5 Compared to gases, silicon dioxide has a very high boiling point of 2 230 °C. With reference to the bonding and structure, explain why silicon dioxide has such a high melting point. (3)

**Giant covalent structure ✓
Many strong covalent bonds ✓
Much higher energy is needed to break these bonds between atoms ✓
(must mention covalent at least once)**

Question 3: [32]

An excess of iron powder reacts with 0,5 dm³ of dilute sulphuric acid.



The graph below shows the volume of hydrogen gas produced at STP as the reaction proceeds.

- 3.1 State the total volume of hydrogen gas formed in dm³. (2)

0,034 dm³ or 34 x 10⁻³ dm³ ✓ read off correctly ✓ converted

- 3.2 Determine the amount (in moles) of hydrogen gas that was produced. (3)

$$n = V / V_m \quad \checkmark = 0,034 / 22,4 \quad \checkmark = 0,00152 \text{ mol} \quad \checkmark$$

The percentage yield of the reaction is 82,50 %

- 3.3 Calculate the maximum amount of hydrogen gas that should have formed. (3)

Actual moles / theoretical moles $\times 100 = \% \text{ yield}$ ✓ can be implied

$$0,00152 / \text{max} \times 100 = 82,50 \quad \checkmark$$

$$\text{maximum amount} = 0,00184 \text{ mol} \quad \checkmark$$

If volume / mass correctly calculated then 2/3. Amount = moles.

- 3.4 Determine the concentration of the sulphuric acid provided originally in this reaction. (4)

**Ratio $\text{H}_2 : \text{H}_2\text{SO}_4$
1 : 1**

$$\therefore n(\text{H}_2\text{SO}_4) = 0,00184 \quad \checkmark$$

$$c = n / V \quad \checkmark = 0,00184 / 0,5 \quad \checkmark = 0,00368 \text{ mol}\cdot\text{dm}^{-3} \quad \checkmark$$

- 3.5 Define reaction rate. (2)

The change in concentration per unit time ✓ of either the reactant or product. ✓

- 3.6 Calculate the average rate of the reaction between 2 and 15 minutes in $\text{cm}^3\cdot\text{min}^{-1}$. (3)

$$\text{Rate} = \text{slope} = \Delta y / \Delta x \quad \checkmark$$

$$= 32 - 6 / 15 - 2 \quad \checkmark \quad \text{accept } 31,5$$

$$= 2 \text{ cm}^3\cdot\text{min}^{-1} \quad \checkmark$$

- 3.7
3.7.1 On the graph grid on page 8 draw in the lines to represent the reactions taking place for conditions 1 and 2. Label these lines clearly. (4)

1. Steeper line ✓ ending at the same product but earlier ✓

2. Flatter gradient ✓ ending at half the product (17cm^3) ✓

- 3.7.2 Explain, in terms of the collision theory, how the temperature change affects the rate of the reaction. (4)

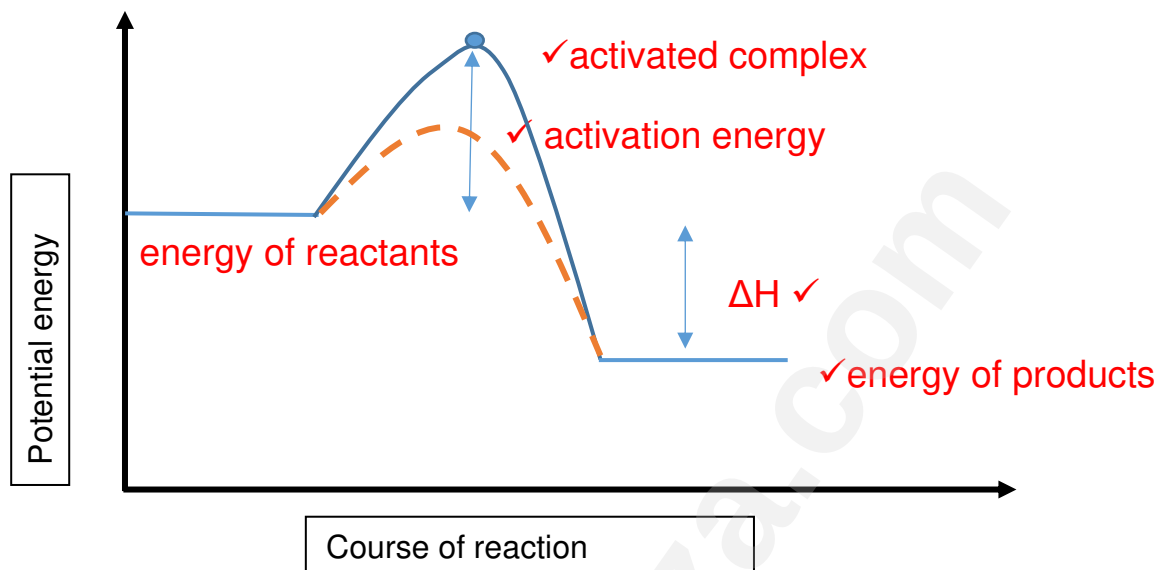
Increased temperature leads to higher kinetic energy of particles ✓

More particles will collide with kinetic energy higher than the activation energy ✓

More collisions and more effective collisions per unit time ✓

Faster reaction rate ✓

- 3.8 On the axes below, complete the potential energy profile for this reaction. Include labels for the energy of products and reactants, the activation energy, the heat of the reaction, and the activated complex. (4)



- 3.9 On the graph above, draw a new line to show how the addition of a catalyst will affect the energy profile for this reaction. (1)

Line with same shape, lower E_a , no change to products or reactants ✓

- 3.10 The Maxwell-Boltzmann distribution for the original reaction is shown below using the solid line.

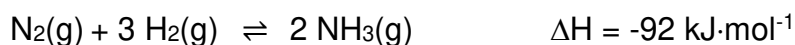
Which of the other two lines indicates the same reaction taking place using a higher concentration of acid? Write only X or Y. (2)

X ✓

Question 4:

[38]

- 4.1 Ammonia is made in the Haber process using the following reaction.



- 4.1.1 Explain what is meant by a reversible reaction. (2)

A reaction where products can be converted back into reactants. ✓✓

- 4.1.2 The ammonia can be removed from the reaction chamber by dissolving it. Refer to the **reaction rate** to explain how this will affect the yield of ammonia. (3)

Removing the reactant particles (NH_3) will decrease the rate of the reverse reaction. ✓

**The forward reaction rate is faster than reverse / both slow down but the reverse reaction slows down more initially ✓
Yield increases ✓**

- 4.1.3 Oratile and Lance investigate how the percentage of ammonia at equilibrium changes with pressure.
The experiment is carried out both at 250 °C and at 350 °C.

- (a) Circle the graph below that correctly shows their results. (2)

II ✓✓

- (b) State Le Chatelier's principle. (2)

When an external stress is applied to a system in chemical equilibrium, the equilibrium point will change in such a way as to counteract the stress. ✓✓

- (c) Hence, fully explain your choice in (a). (6)

Increased pressure favours the reaction producing less gas particles ✓

The forward reaction is favoured ✓

Higher % ✓

Increased temperature favours the endothermic reaction ✓

Favours the reverse reaction ✓

% lower ✓

OR

Decreased temperature favours exothermic reaction ✓

Favours the forward reaction ✓

% higher ✓

- 4.1.4 Write the K_c expression for the production of ammonia. (2)

$$K_c = \frac{[\text{NH}_3]^2}{[\text{N}_2][\text{H}_2]^3} \quad \checkmark \checkmark$$

- 4.1.5 5 mol of nitrogen gas was introduced into the 2,50 dm³ reaction vessel with the hydrogen gas. The K_c value for this reaction is 0,53 at 350 °C. At equilibrium at 350°C, the vessel was analysed and 2,8 mol of nitrogen was still present. Determine the concentration of the hydrogen gas at equilibrium. (5)

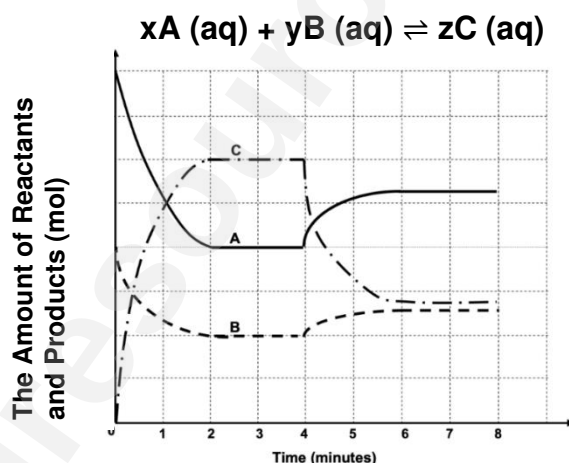
Can use RICE table.

Calculate the change in N_2 as 2,2 moles ✓
Using ratios to get change in H_2 as 6,6 moles
and NH_3 as 4,4 moles ✓
Equilibrium concentrations method: $\div 2,5$ ✓

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

$$0,53 = \frac{(1,76)^2}{(1,12)[H_2]^2} \quad \checkmark \quad [H_2] = 1,73 \text{ mol}\cdot\text{dm}^{-3} \quad \checkmark$$

- 4.2 The chemical reaction below represents a hypothetical reaction that reaches equilibrium in a closed container at room temperature. The molar coefficients of the reaction are represented by the letters x, y and z.



- 4.2.1 State what is meant by a dynamic equilibrium. (2)

Rate of the forward reaction equals the rate of the reverse reaction ✓
Concentrations remain constant ✓

- 4.2.2 At what time was the initial equilibrium reached? (1)

2 minutes ✓

- 4.2.3 Using the graph, deduce and write down the simplest values of x and z. (2)

$x = 2$ ✓ $z = 3$ ✓ ($y = 1$)

4.2.4 At 4 minutes the reaction mixture was heated.

- (a) State whether the forward reaction is endothermic or exothermic. (1)

Exothermic ✓

- (b) Use the graph to explain your answer in (a). (4)

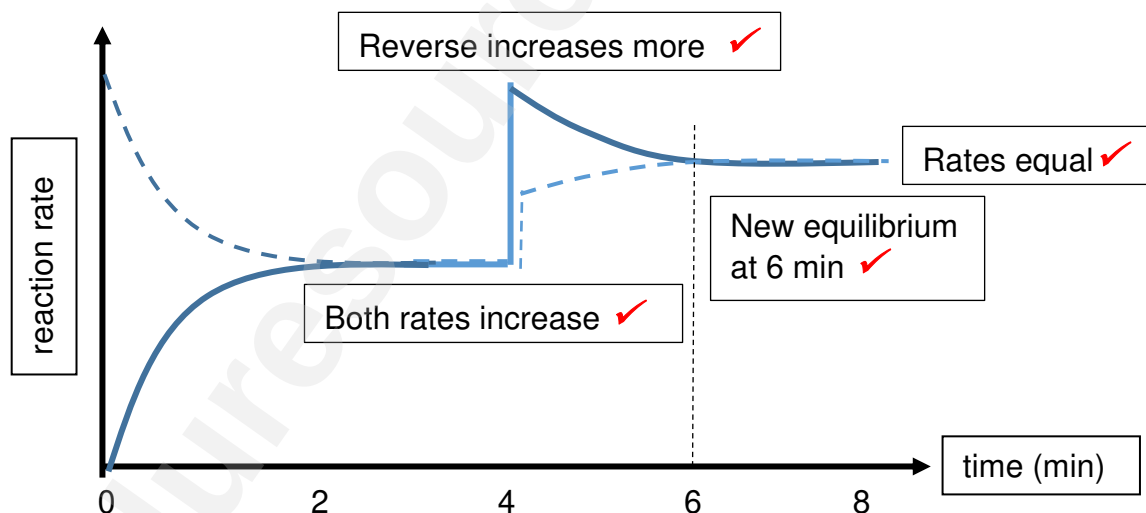
**Increase in temperature according to LCP will favour the endothermic reaction ✓ to absorb heat and lower the temp ✓
The reverse reaction is favoured according to the graph ✓
The reverse reaction is therefore endothermic ✓**
(Forward reaction is exothermic.)

4.2.5 At 8 minutes the pressure was decreased. State the effect that this change will have on the K_c value for this reaction.

- Only state INCREASE, DECREASE or REMAIN THE SAME. (2)

Remain the same ✓✓

4.2.6 On the axes provided below draw a sketch graph of the rate vs time for this reaction up to 8 minutes. (4)



Question 5:

[18]

- 5.1 Define *standard solution*. (1)

A solution of known concentration. ✓

- 5.2 Write the dissociation reaction for the sodium hydroxide in water. Include state symbols. (2)



- 5.3 Calculate the concentration of the hydronium ions present in the 0,5 mol·dm⁻³ sodium hydroxide solution at 25°C. (3)

$$\begin{aligned} [\text{H}_3\text{O}^+][\text{OH}^-] &= 1 \times 10^{-14} \quad \checkmark \\ [\text{H}_3\text{O}^+](0,5) &= 1 \times 10^{-14} \quad \checkmark \\ [\text{H}_3\text{O}^+] &= 2 \times 10^{-14} \text{ mol} \cdot \text{dm}^{-3} \quad \checkmark \end{aligned}$$

- 5.4 Define the *equivalence point*. (2)

The point where an acid and base have reacted so that neither is in excess. $\checkmark \checkmark$

- 5.5 Explain how the maximum temperature shown on this graph can be used as an indication of the equivalence point. (2)

It is an exothermic reaction which will release heat and the increase in temperature will be large $\checkmark$
When the reaction reaches the equivalence point, less heat will be produced $\checkmark$

- 5.6 a) Read the equivalence point off the graph. (1)

$$22 \text{ cm}^3 \quad \checkmark \quad \text{or } 8,8^\circ \text{C}$$

- b) Hence, calculate the concentration of the acid. (4)

$$\begin{aligned} \text{NaOH: } c &= n/V \\ 0,5 &= n / 0,20 \quad \checkmark \\ n &= 0,1 \text{ mol} \end{aligned}$$



$$n(\text{H}_2\text{SO}_4) = 0,05 \text{ mol} \quad \checkmark$$

$$\begin{aligned} \text{H}_2\text{SO}_4 : c &= n/V \\ &= 0,05 / 0,022 \text{ (conversion)} \quad \checkmark \\ &= 2,27 \text{ mol} \cdot \text{dm}^{-3} \quad \checkmark \end{aligned}$$

$$\begin{aligned} \text{OR: } \frac{c_a V_a}{c_b V_b} &= \frac{a}{b} \\ \frac{C_a(0,022)}{(0,5)(0,2)} &= \frac{1}{2} \quad \checkmark \\ C_a &= 2,27 \text{ mol} \cdot \text{dm}^{-3} \quad \checkmark \end{aligned}$$

- 5.7 At the endpoint of this titration the solution has a pH of 7. When the titration was repeated using sodium hydroxide and hydrofluoric acid, the pH at the equivalence point was higher. Explain the higher pH using an appropriate hydrolysis equation. (3)

(Salt is NaF - Na⁺ does not undergo hydrolysis but F⁻ does)



[OH⁻] > [H₃O⁺] and therefore the pH will be higher than 7 $\checkmark$

Question 6:

[23]

- 6.1 Define *reduction*. (1)

The gain of electrons ✓

- 6.2 Identify the cathode. (1)

Platinum or Pt ✓

Please note: SAGS: "The SHE will only be assessed in the context of its use as a reference electrode and therefore will always be shown to be connected as the anode."
To avoid confusion, this question should have said: Identify the cathode when the cell is operating spontaneously.

- 6.3 a) State two relevant standard conditions that are not included in the diagram. (2)

The hydrogen gas must be at 1 atm ✓

The temperature should be 25 °C ✓

- b) Explain why the platinum electrode has the shape shown in the diagram rather than using a straight piece of wire. (2)

This shape has a larger surface area

Leads to more effective electron transfer / faster reaction / higher current ✓

- 6.4 Calculate the reading on the voltmeter. (see note above) (3)

$$\begin{aligned} E^{\ominus}_{\text{cell}} &= E^{\ominus}_{\text{cathode}} - E^{\ominus}_{\text{anode}} \quad \checkmark \\ &= 0 - (-0,25) \quad \checkmark \\ &= 0,25 \text{ V} \quad \checkmark \end{aligned}$$

- 6.5 The switch is closed and the ammeter shows a reading of 1,55 A.

- 6.5.1 On the diagram on page 20 show the direction of electron movement through the ammeter. (2)

From Ni to Pt (left to right) ✓✓ (cell operating spontaneously)

- 6.5.2 Write down the balanced chemical equation for the spontaneous oxidation half reaction that occurs. (2)



- 6.5.3 Calculate the change in mass of the nickel electrode in 2 hours. State whether the mass calculated was GAINED or LOST by the electrode. (8)

$$q = It \quad \checkmark \quad q = nF \quad \checkmark$$

$$= (1,55) (2 \times 60 \times 60) \quad \checkmark \quad 11160 = n (96\,500) \quad \checkmark$$

$$= 11160 \text{ C} \quad n = 0,11565 \text{ (mol of electrons)}$$

$$e^- : \text{Ni}$$

$$2 : 1 \quad \checkmark \quad \therefore n(\text{Ni}) = 0,0578$$

For nickel:

$$n = \frac{m}{M}$$

$$0,0578 = \frac{m}{59} \quad \checkmark$$

$$m = 3,41 \text{ g} \quad \checkmark \quad \text{This mass was LOST} \quad \checkmark$$

- 6.5.4 Describe how the salt bridge helps to maintain the electric neutrality of the nickel half-cell by referring to the movement of ions. (2)

Positive nickel ions form (due to oxidation of Ni) causing the solution to become more positive. ✓
The electrolyte solution in the salt bridge provides negative ions to balance this charge ✓ and keep the solution neutral.
OR Excess positive ions move out of this half-cell through the salt bridge into the cathode electrolyte.
(answer must be specific to nickel half-cell)

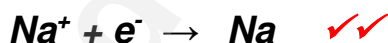
Question 7: [16]

7.1

- 7.1.1 State the energy conversion taking place in this cell. (2)

Electrical to chemical ✓✓

- 7.1.2 Write the equation for the reduction half-reaction in this type of cell. (2)



- 7.1.3 (a) With reference to the table of standard potentials, explain why oxygen gas can be theoretically predicted to be the anode product when NaCl(aq) is electrolysed. (2)

At standard conditions water is a stronger reducing agent than chloride ✓ and is oxidised to form oxygen gas. ✓

- (b) Explain why then, when brine is electrolysed, chlorine gas is formed instead at the anode. (2)

Brine is very concentrated. The chloride ion concentration is higher than standard ✓

The E° value becomes less positive / increasing reducing ability / rate of oxidation of chloride ions increase / chloride is more likely to be oxidised than H_2O ✓

7.2

- 7.2.1 Define an *electrolyte*. (2)

A substance that can conduct electricity by forming free ions ✓ when molten or when dissolved in a solution ✓

- 7.2.2 Explain why solid aluminium oxide cannot be electrolysed. (2)

**(Ions are trapped in the ionic lattice by electrostatic forces / or kept together by many strong electrostatic forces)
There are no free ions ✓ to conduct electricity ✓**

- 7.2.3 Write down the number/s of the reactions that take place at the anode. (2)

2 ✓ and 3 ✓

- 7.2.4 With reference to the standard electrode potential table, explain why no aluminium formed in the lab. (2)

**Water is a stronger oxidising agent than aluminium ions. ✓
Therefore the water would be reduced to $H_2(g)$. ✓
The Al^{3+} would not be reduced to aluminium.**

Note: nitrate is an anion (attracted to anode) and the reduction of nitrate would require an acidic medium $\therefore$ not accepted.

Question 8: [24]

- 8.1 State which compound/s (4)

8.1.1 can be considered to be hydrocarbons? **B, E and F ✓**

8.1.2 is/are saturated hydrocarbons? **B ✓**

8.1.3 has/have a pH of less than 7 in an aqueous solution? **D ✓**

8.1.4 belong to the same homologous series? **E and F ✓**

8.2 Name the functional group of compound **A**. (1)

hydroxyl ✓

8.3 Give the IUPAC names for compounds **C**, **D** and **E** (6)

C: **ethyl** ✓ **propanoate** ✓

D: **propanoic acid** ✓

E: **2 – methylbut – 2 – ene**

✓ ✓ ✓

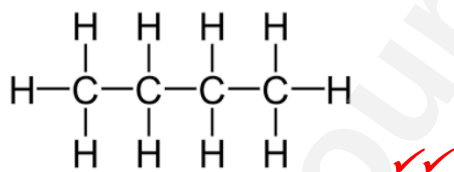
8.4 Define *structural isomers*. (2)

Compounds with the same molecular formula but different structural formulae. ✓✓

8.5 Give the condensed structural formula for a positional isomer of compound **E**. (2)

CH₂ C (CH₃) CH₂ CH₃ ✓✓

8.6 Draw the structural formula for a chain isomer of compound **B**. (2)



8.7 Give the IUPAC name for a straight-chain functional isomer of compound **C**. (2)

pent ✓ **anoic acid** ✓

8.8 A mixture of gas containing compounds **D** and **F** is cooled slowly to separate them.

8.8.1 State which one of the two substances will liquefy first. (1)

D ✓

8.8.2 Explain your answer in Question 8.8.1 by referring to the intermolecular forces present in the substances. (4)

D Hydrogen bond IMF ✓ **F London IMF** ✓

D stronger IMF ✓ **Particles in D will attract each other stronger and liquefy first** ✓

Question 9:**[15]**

9.1 State the general reaction type for: (2)

9.1.1 Reaction III: **combustion** ✓

9.1.2 Reaction IV: **elimination** ✓

Must learn which is GENERAL type and which is SPECIFIC type. Don't write both.

9.2 State the specific reaction type for: (2)

9.2.1 Reaction I: **hydro halogenation** ✓

9.2.2 Reaction II: **hydrolysis** ✓

9.3 Using molecular formulae, write a balanced chemical equation for reaction (IV). Assume that Compound **A** and only one other compound are produced. (3)



9.4 Write down the general formula for the homologous series to which compound **A** belongs. (1)



9.5 Compounds **A** and **B** can both form $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br}$. Explain why **A** reacts spontaneously while **B** needs UV light. (3)

Compound A is unsaturated and is reactive (double bonds) ✓
Compound B is less reactive as it is saturated (single bonds) ✓
Therefore B needs extra energy for the reaction to take place supplied by the UV light. ✓ (not a catalyst)

9.6 Using structural formulae, write a balanced chemical equation for the formation of Compound **C**. (4)

✓✓✓✓ one for each structure (condensed formulae used -1)

