Answers

1	2	3	4	5	6	7	8
С	С	В	В	Α	В	В	С
9	10	11	12	13	14	15	16
Α	В	В	Α	Α	С	D	С
17	18	19	20				
D	D	D	С				

Answers:

- 1 (a) (i) Water: Hydrogen Bonding CCl₄: Dispersion Forces [1/2 each]
 - (ii)

	Water	Tetrachloromethane
Hydrocarbon Chain	Permanent dipole- induced dipole interactions / dispersion forces	Dispersion forces
Carboxylic acid functional group	Hydrogen bonds	Permanent dipole- induced dipole interactions / dispersion forces

[1/2 each]

- (ii) The energy released in forming new interactions between water and caprylic acid is insufficient to compensate for the energy required to break the existing interactions. However, the energy released is sufficient to compensate the energy required when in CCl₄. [1]
- (b) (i) When Br_2 approaches the alkene, <u>the electron cloud on Br_2 is distorted to form a</u> <u>temporary dipole moment</u> that causes it to be electron deficient. [1]

ICl is a <u>polar molecule</u>, the <u>more electronegative Cl causes I to be electron deficient</u>. [1]

- (ii) The reaction is kept in the dark to prevent the possibility of free radical substitution. [1]
- (iii) Mechanism for electrophilic addition.

Award 1 mark per step.

Deduct ½ per mistake (e.g. no charge separation, missing/ wrongly drawn arrows, missing slow step, wrong intermediate)

- (c) The <u>electrons in the benzene ring are delocalized</u>, hence there is <u>resonance stabilization</u>. If benzene undergoes addition, the stabilization due to resonance is lost and it destabilizes the compound. [1]
- (d) Step 1: CH₃Cl, AlCl₃ or FeCl₃, heat
 Step 2: KMnO₄. Dilute H₂SO₄, heat [1 mark per step]



- (iii) C_nH_{2n}O_n [1]
- (iv) $C_{12}H_{22}O_{11}$ [1]
- (b) (i) Circles laevorotatory.

The final glucose/fructose mixture is laevorotatory (A_{final} is negative). As glucose is dextrorotatory, fructose must be laevorotatory for this to be possible. [1]

(half mark for answers which only point out that the observed rotation is becoming less and less positive)

- (ii) H⁺ is a catalyst and overall remains unchanged and not used up (or is regenerated), hence its concentration is constant. [1]
- (iii) Finding half life = 82 min [1 subtract 0.5 if no construction lines]

As the half-life of sucrose is <u>constant</u> at 82 min, the order with respect to sucrose is one (<u>x=1</u>). [1]

- (iv) $k_{eff} = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{82} = 0.00845 \text{ min}^{-1}$ [1] for working+value, [1] for units
- (v) Initial rate = $0.00845 \times 0.580 \div 2 = 0.00245 \text{ mol dm}^{-3} \text{ min}^{-1}$ [1]
- (vi) The temperature of the solutions could be kept lower than 30 °C. [1]

The concentration of HCl used could be lower than 1 mol dm⁻³. [1]

3 (a) (i) There are no/negligible intermolecular forces of attraction between the gas particles. OR

The volume occupied by the gas particles is negligible compared to the volume of the container/ the gas molecules have zero volume. OR

Collisions between the gas particles are elastic / no loss of kinetic energy on collision.

Any of the above two points [2]

- (ii) As temperature increases, the gas molecules possess <u>more kinetic energy</u> [1] and <u>collide more frequently OR more forcefully with the walls of the container</u>. [1]
- (iii) PV = (m/M_r)RT Choose correct point on graph (any point from B to C) [1] Using point B, m = (0.8 x 101325 x 1.25 x 10⁻³ x 32.0) / (8.31 x 90) = 4.34 g [1]
- (iv) $\begin{array}{ccc} 3O_2(g) \rightarrow 2O_3(g) \\ \text{before reaction / atm} & 1.2 & 0 \\ \text{after reaction / atm} & 1.2 3x & 2x \\ \text{total pressure = } 1.2 3x + 2x = 1.2 x = 1.14 \\ \Rightarrow x = 0.06 \quad \textbf{[1]} \\ \text{partial pressure of oxygen = } 1.2 0.06 \times 3 = 1.02 \text{ atm} \quad \textbf{[1]} \end{array}$
- **(b)** (i) Given $3/2 O_2(g) \rightarrow O_3(g)$ $\Delta H = +143 \text{ kJ mol}^{-1}$

So standard enthalpy change of **Reaction 1** = $+143 \times 2 = +286 \text{ kJ mol}^{-1}$ [1]

Entropy change for **Reaction 1** is <u>negative</u> because the <u>number of moles of gas</u> <u>molecules decreases</u> after the reaction, so there are fewer ways of distributing the molecules and their energies. **[1]**

Since ΔH^{Θ} is positive and ΔS^{Θ} is negative, and $\Delta G^{\Theta} = \Delta H^{\Theta} - T\Delta S^{\Theta}$ (some link between first 2 points and ΔG^{Θ}), ΔG^{Θ} is positive at all temperatures, and hence it is non-spontaneous at all temperatures under standard pressure. [1]

- (ii) The <u>lightning</u> provides an external <u>input of energy</u> to drive the non-spontaneous reaction. [1]
- (iii) Since △G[⊕] is positive, K < 1, so the <u>equilibrium position will lie more on the left</u> OR the equilibrium is <u>reactant-favoured</u> OR the extent of reaction at equilibrium is <u>less than half complete</u> [1]
- (i) Reactions 1 and 4 may be slower because they involve <u>breaking of covalent bonds</u> and <u>higher E_a is likely involved</u>. [1]
- (ii) Cl• + O₃ → ClO• + O₂ ClO• + O → Cl• + O₂
 [1] elementary steps add up to give overall eqn for reaction (3)
 [1] Cl• is regenerated, ClO• is produced in one step and used up in the next

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(b)		Test		Observations				
				A			В	
		Add a little acidified potassium		Purple KMn	Purple KMnO ₄ Purple		KMnO4	
		manganate(VII) to a	a sample of each	decolourise	S,	decolou	rises, no	
		bottle, and place in	a heated water ba	th. effervescen	ce seen	efferves	cence seen	
		[1] correct descriptic [1] correct observation [Total: 2]	n of a chemical te ons for each comp	st that would suc ound	cessfully c	listinguis	h A and B	
(C)	(i)	η_{u} reacted with the sample = η_{u} total – η_{u} left unreacted						
		.11	- ^{35.00} × 2	19.65×1.00	- 5 035 v	10-2		
			$-\frac{1000}{1000}$ ^ 2.	$100 - \frac{1000}{1000} \times 1.00$	- 5.055 ^	10		
			= 5.04 × 1	0 ⁻ ² mol (3 s.f.)				[1]
	<i>(</i> ii)	16.4	0					
	(11)	η_{CO_2} produced = $\frac{16.4}{2270}$	<u>0</u> = 7.225 × 10⁻⁴ m	าดไ				
		Y ₂ (CO ₃) ₃ •3H ₂ O + 6H	$Cl \rightarrow 2YCl_3 + 3CC$	D ₂ + 6H ₂ O	(eq	uation n	ot necessary))
		So, η_{H^+} reacted with the carbonate = 7.225 × 10 ⁻⁴ × $\frac{6}{3}$ = 1.4449 × 10 ⁻³ mol						
				=	1.45 × 10	^{-s} mol (3	s.t.)	[1]
	(iii)		Y	н	0			
		mass in 100 g /g	63.5	2.14	34.3	36		
		amount / mol	$\frac{63.5}{88.9} = 0.714$	$\frac{2.14}{1.0} = 2.14$	$\frac{34.36}{16.0} =$	2.148		
		mole ratio	1	3	3			
		Therefore, Q is yttrium(III) hydroxide, Y(OH) ₃						
		$12 \cup 3 + 5 \cup 2 \cup \rightarrow 2 \cup (\cup \square)_3$						
		 [1] for correct formula of Q from calculations [1] for correct equation [Total: 2] 						

(iv	$Y(OH_3) + 3HCl \rightarrow YCl_3 + 3H_2O$
	Whether from the hydroxide or oxide, each mole of "Y" requires 3 times the no. of moles of HCl to react completely. (Hence it doesn't matter what proportion of the oxide has converted to hydroxide \Rightarrow reacting ratio with HCl is still the same!)
	One way of calculating (some steps can be skipped/combined):
	η_{H^+} reacted with the yttrium oxide and hydroxide = 5.035 × 10 ⁻² – 1.445 × 10 ⁻³ = 4.891 × 10 ⁻² mol
	$\therefore \eta_{Y_2O_3} \text{ in original sample} = \frac{1}{6} \times 4.891 \times 10^{-2} = 8.151 \times 10^{-3} \text{ mol (from equation given)}$
	So, mass of Y ₂ O ₃ in original sample = $8.151 \times 10^{-3} \times 225.8 = 1.840$ g % purity = $\frac{1.840}{2.00} \times 100$ % = 92.0 % (3 s.f.)
	[1] subtraction of acid reacted with carbonate to get amount of acid reacted with oxide/hydroxide (allow e.c.f. from wrong answer in (i) and/or(ii)
	[1] correct use of equation mole ratio to get original amount/mass of yttrium oxide (allow e.c.f. from previous step in the calculation, but do not award if mole ratio of acid to yttrium oxide is incorrect)
	[1] % purity calculation
	[Total: 3]



(b)	The first ionisation energy for the elements increases across the period.[1]
	The nuclear charge increases while the shielding effect remains relatively constant so the effective nuclear charge increases across the period.
	Hence <u>more energy is required</u> to <u>remove the first valence electron</u> across the period. [1]
	There are two anomalies in the trend.
	The <u>first IE of A/ is less than Mg</u> since the <u>first valence electron in A/ is found in the</u> <u>3p orbital</u> which is <u>further from the nucleus</u> compared to the <u>first valence electron of</u> <u>Mg</u> which is in the 3s orbital. [1]
	The <u>first IE of S is less than P</u> since P has a $3p^3$ configuration while <u>S has a $3p^4$</u> <u>configuration</u> where one of the orbitals has <u>a pair of electrons which experiences inter-electronic repulsion</u> and it is easier to remove the first valence electron for S compared to P. [1]
(c)	Argon exists as non-polar atoms with dispersion forces between them.[1]
	Hydrogen peroxideexists as a simple covalent compoundwith polar molecules withhydrogen bondingbetween them. (Accept if molecules used to describe H_2O_2)[1]
	Diamond exists as a giant covalent (macromolecular) structure with strong covalent bonds between <u>C atoms</u> . [1]
	Argon has the lowest melting point as <u>dispersion forces</u> are the <u>weakest bonding</u> among the three forms and hence the <u>least energy</u> is required to <u>break</u> them. <u>Diamond</u> has the <u>strongest bonding</u> since its extensive <u>covalent bonding is stronger than dispersion</u> <u>forces</u> and hydrogen bonding. Hence it has the highest melting point. [1]
	*Last mark to be awarded for comparison of strongest and weakest form of bonding and related to the amount of energy required to break the bonding.

3(a)	(i)	·Ö·
		•• -* Č * -••
		$ \cdot Cl \cdot \cdot Cl \cdot Cl$
	(ii)	
	(11)	
		sp ² orbitals (ignore wrong labels) [1]
(b)	(i)	Let the amount of CO produced be <i>x</i> mol
		$COCl_2(g)$ \rightleftharpoons $CO(g)$ $+$ $Cl_2(g)$ Initial amount / mol0.20000Change in amount / mol $-\mathbf{x}$ $+\mathbf{x}$ $+\mathbf{x}$ Equilibrium amount / mol0.200 - \mathbf{x} \mathbf{x} \mathbf{x}
		Total amount of gas at equilibrium = $0.200 + x = 0.319$ mol $\Rightarrow x = 0.119$ mol
		At equilibrium, [CO] = [Cl_2] = 0.119 ÷ 12.5 = <u>0.00952 mol dm⁻³</u> [$COCl_2$] = (0.200 – 0.119) ÷ 12.5 = <u>0.00648 mol dm⁻³</u>
		Percentage of COC l_2 dissociated = (0.119 ÷ 0.200) × 100 % = <u>59.5 %</u>
		Relevant working to find \mathbf{x} or other relevant equilibrium amounts [1] Concentrations of CO and Cl_2 [1] Concentration of COCl ₂ [1]
		% dissociation (allow ecf from previous marks if did not divide by volume) [1]
	(ii)	$K_{\rm c} = \frac{[{\rm CO}][{\rm C}l_2]}{[{\rm COC}l_1]} = \frac{0.00952^2}{0.00648} = 0.013986 = 0.0140 \text{ mol dm}^{-3} (3 \text{ s.f.})$
		$Correct K_c expression [1]$
		Correct final answer with units [1]
	(iii)	$\Delta G_{\rm r}^{\rm r} = -RT \ln K$
		$\Rightarrow K = e^{-\frac{\Delta G_{\rm f}}{RT}} = e^{-\frac{67700}{(8.31)(298)}} = 1.34 \times 10^{-12} (3 \text{s.f.}) $ [1]
	(iv)	As temperature decreases from 770 K to 298 K, K_c decreases, meaning the reactant- product ratio decreases. Therefore, the <u>backward reaction is favoured</u> , which is exothermic since temperature has decreased. Hence, ΔH for the dissociation (forward reaction) is <u>positive</u> .
		Link change in K_c to favouring of the correct reaction [1] Correct final deduction of sign of ΔH [1] Allow ecf from (iii), i.e. K_c increase $\Rightarrow \Delta H < 0$

(c)	(i)	CO is a Brønsted–Lowry base/Lewis base.[1]A/Cl ₃ is a Lewis acid.[1]
	(ii)	Electrophilic substitution H - C = 0 $H + H$
		A/Cl_{4}^{-} H
	(iii)	Reduction.[1]Loss of $O/apin of H/change in oxidation number of benzylic C from +1 to -3[1]$
	(i)()	Methylhenzene is more reactive toward electrophiles than henzene (due to its electron
	(1V)	donating methyl substituent). It undergoes <u>further electrophilic substitution</u> to form <u>multi-</u> <u>substituted products</u> , hence lowering the yield of methylbenzene.
		Link higher reactivity of methylbenzene to a reason why yield is lowered [1] (e.g. multi-substituted products, or methylbenzene reacts further)



(d)	(i)	Let the formula of the hydrocarbon be C_xH_y .
		$(y_1, y_2) = (y_1, y_2) (x_1, y_2) (x_2, y_3) (x_1, y_2) (x_2, y_3) (x_1, y_2) (x_2, y_3) (x_1, y_2) (x_2, y_3) (x_1, y_3) (x_2, y_3) (x_1, y_3) (x_2, y_3) (x_3, y_3) (x_1, y_3) (x_2, y_3) (x_3, y_3) (x_3, y_3) (x_1, y_3) (x_2, y_3) (x_3, y$
		$C_xH_y(g) + (x + \frac{1}{4})O_2(g) \rightarrow xOO_2(g) + \frac{1}{2}\Pi_2O(l)$
		Initial volume / cm_3^3 10 a 0 -
		Final volume / cm^3 0 a^2 60 -
		Reacting volume / cm ² 10 $a - a^2$ 60 -
		Volume ratio and mole ratio of $CO_2:C_xH_y$ is $6:1 \Rightarrow x = 6$ [1]
		Contraction in volume by 30 cm ³ \Rightarrow (10 + a) – (60 + a ') = 30
		Volume of O_2 reacted = $a - a' = 80$ cm ³
		$\Rightarrow (x + \frac{y}{4}) = 8 \Rightarrow \underline{y} = 8 $ [1]
		[Total: 2]
	(ii)	show calc of ratio of P:H ₂ = 1:3 (3 moles of C=C present in every mole of P) [1] +[1] for
		calculations
		Type of reaction: addition/reduction [1]
		Methanal formed after ozonolysis \Rightarrow Presence of =CH ₂ [1]
		Reaction with ad bromine: electrophilic addition [1]
		P Q R OH Br
		R: position of OH and Br interchangeable
		[Total: 8]