2024 Y6 Preliminary Examination
H2 Chemistry 9729 Paper 1
Suggested Solutions

Answer Key

1	2	3	4	5
B	**D**	**B**	**D**	**B**

6	7	8	9	10
A	**D**	**C**	**B**	**A**

11	12	13	14	15
C	**C**	**A**	**D**	**A**

16	17	18	19	20
B	**D**	**D**	**A**	**C**

21	22	23	24	25
A	**D**	**C**	**C**	**C**

26	27	28	29	30
B	**C**	**A**	**B**	**D**

1	**B** P: [Ne]$3s^2 3p^3$ No. of unpaired electrons = 3	
✗	**1**	Ti: [Ar]$3d^2 4s^2$ Ti^{2+}: [Ar]$3d^2$ No. of unpaired electrons = 2
✓	**2**	V: [Ar]$3d^3 4s^2$ V^{2+}: [Ar]$3d^3$ No. of unpaired electrons = 3
✓	**3**	Cr: [Ar]$3d^5 4s^1$ Cr^{3+}: [Ar]$3d^3$ No. of unpaired electrons = 3

2	**D**
	ΔH_1 = 2nd IE of Si = +1580 kJ mol^{-1} ΔH_2 = 2nd IE of Al = +1820 kJ mol^{-1} ΔH_3 = sum of 1st & 2nd IE of Si = 786 + 1580 = +2366 kJ mol^{-1} order of decreasing enthalpy change: $\Delta H_3 > \Delta H_2 > \Delta H_1$

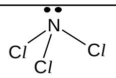
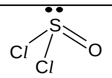
3	**B**
	$2H_2S + 3O_2 \rightarrow 2SO_2 + 2H_2O$ $CS_2 + 3O_2 \rightarrow CO_2 + 2SO_2$ Hence, $SO_2 : CO_2$ will be 4 : 1. ⇒ Options A & C are incorrect. Both CO_2 and CS_2 are linear around the central C atom so both are non-polar molecules. CS_2 has a larger, more polarisable electron cloud than CO_2 so CS_2 has stronger instantaneous dipole-induced dipole interactions between molecules. The more significant intermolecular forces result in greater deviation of CS_2 from ideal behaviour.

<table>
<tr><th>4</th><th colspan="2">D</th></tr>
<tr><td>✗</td><td>A</td><td>magnitude of lattice energy $\propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$

This is a true statement (Ca^{2+}; 0.099 nm, Na^+; 0.095 nm). but a larger cationic radius leads to a less exothermic lattice energy so this does not explain the higher melting point of CaO.</td></tr>
<tr><td>✗</td><td>B</td><td>This is a true statement as Ca^{2+} has a higher charge than Na^+ but their ionic radii are similar (Ca^{2+}; 0.099 nm, Na^+; 0.095 nm).

However, magnitude of lattice energy $\propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$ so charge density $\propto \frac{q}{r}$ of the cation alone is not representative of the lattice energy of the compound.</td></tr>
<tr><td>✗</td><td>C</td><td>This is a true statement:
<table>
<tr><th colspan="2">sum of ionic radii</th></tr>
<tr><td>CaO</td><td>NaF</td></tr>
<tr><td>0.099 + 0.140
= 0.239 nm</td><td>0.095 + 0.136
= 0.231 nm</td></tr>
</table>
However, a larger sum of ionic radii leads to a less exothermic lattice energy so this does not explain the higher melting point of CaO.</td></tr>
<tr><td>✓</td><td>D</td><td>This is a true statement and the magnitude of lattice energy is larger when the magnitude of ionic charges are larger.</td></tr>
</table>

5	**B**

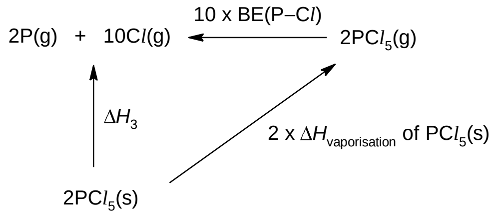
molecule	structure	shape	polarity
NCl_3		trigonal pyramidal	polar
HCN	H−C≡N	linear	polar
$BeCl_2$	Cl−Be−Cl	linear	non-polar
$SOCl_2$		trigonal pyramidal	polar

Hence, NCl_3 and $SOCl_2$ are polar and have the same shape.

6	A
	Solid **X** is Na_2O which is soluble in water to form the colourless solution of $NaOH(aq)$. On adding $CuSO_4(s)$ to $NaOH(aq)$, pale blue ppt of $Cu(OH)_2$ is formed. $Na_2O(s)$ is also soluble in $NaOH(aq)$ as it readily dissolves in water. Solid **Y** is insoluble in water and could be either $Al_2O_3(s)$ or $SiO_2(s)$. Since **Y** is soluble in dilute $NaOH(aq)$, **Y** is $Al_2O_3(s)$ which is amphoteric. Solid **X** (Na_2O) is soluble in $HCl(aq)$ as it readily dissolves in water. Solid **Y** (Al_2O_3) undergoes acid-base reaction with $HCl(aq)$ to form a colourless solution: $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$

7	D	
✗	A	As ionic radius increases down the group, charge density and hence polarising power of the cation decreases.
✗	B	The reducing (not oxidising) power of the elements increases.
✗	C	As polarising power of the cation decreases, the electron cloud of the chloride anion is polarised to a smaller extent so covalent character of the metal chlorides decreases.
✓	D	As polarising power of the cation decreases, the electron cloud of the carbonate anion is polarised to a smaller extent and the covalent bonds in the carbonate anion are weakened to a smaller extent. More energy is required to decompose the metal carbonate so thermal stability of the metal carbonates increases.

8	C
	Cl_2 is a stronger oxidising agent than Br_2 so Cl_2 will oxidise Br^- to Br_2 while itself is reduced to Cl^-. $Cl_2(aq) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq)$ The colourless KBr solution turns orange due to the mixture of orange $Br_2(aq)$ formed and remaining pale yellow $Cl_2(aq)$ so options A & D are incorrect. On addition of $AgNO_3(aq)$, white ppt of $AgCl$ is formed. There is no remaining $Br^-(aq)$ ions to form cream ppt of AgBr. $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

9	B	
✓	1	$\Delta H_2 = 5 \times BE(Cl-Cl) = 5 \times 244 = +1220$ kJ mol^{-1} $\Delta H_1 = 2 \times \Delta H^{\ominus}_{atomisation}$ of P(s) so $\Delta H_1 > 0$ since atomisation is an endothermic process. Hence $\Delta H_1 + \Delta H_2 > +1220$ kJ mol^{-1}
✗	2	Note: Reactants and products are in gaseous state when bond energy is used. $\Delta H_3 \neq 10 \times$ P−Cl bond energy $\Delta H_3 = (2 \times \Delta H_{vaporisation}$ of $PCl_5(s)) + (10 \times$ P−Cl bond energy) 
✓	3	2 mol of $PCl_5(s)$ are formed from the constituent elements in their standard states.

10	A
	$\Delta S < 0$ due to a decrease in number of moles of gas (4 mol to 2 mol). Hence $-T\Delta S > 0$ Since $\Delta H < 0$ and $\Delta G = \Delta H - T\Delta S$, $\Delta G < 0$ when $\lvert -T\Delta S \rvert < \lvert \Delta H \rvert$ Hence the reaction is spontaneous only at low temperature.

11	C
	Let the unknown iodine oxide be I_xO_y. Given, I_xO_y : I^- : I_2 0.02 : 0.2 : 0.12 1 : 10 : 6 In order to balance the number of I atoms, x = 2 Iodine in I_2O_y is reduced to I_2. Iodide is oxidised to I_2. Since [O]: $2I^- \rightarrow I_2 + 2e^-$ Hence, number of mol. of electrons lost by 10 mol. of KI = 10 mol = number of mol. of electrons gained by 1 mol. of I_2O_y So, mol ratio of I_2O_y : e^- gained = 1:10 ∴mol ratio of *each* I in I_2O_y : e^- gained = 1:5 ∴ the oxidation state of each I in I_2O_y is +5 to produce I_2.

12	C
	$p_x \propto [Cl_2]$ Since it is given that the reaction is zero order w.r.t. Cl_2, the rate of reaction should remain unchanged when there is a change to $[Cl_2]$. The **gradient** of p_x vs time graph is indicative of the rate of reaction. Hence, the **gradient** of p_x vs time graph should remain **constant** even when p_x decreases with time due to reaction (downward sloping straight line).

13	A	
✓	1	Colorimetry can be used to measure how the light absorbance of the reaction solution changes at regular intervals as the reaction takes place. The light absorbance is proportional to the colour intensity which is in turn proportional to the concentration of the coloured substance. The rate of reaction is directly proportional to the rate of decrease (or increase) in colour intensity of the reactant (or product).
✓	2	*Concept*: All total volumes were kept constant for all experiments, hence [reactant] $\propto$ V_{reactant}. Comparing Expts 1 & 4, when volumes of **B** and **Y** were kept constant, while volume of the coloured solution **A** was doubled, time taken was doubled. ⇨ rate of decolourisation remained constant. ∴Order of reaction w.r.t. **A** is 0. Comparing Expts 1 & 2, when volumes of **A** and **Y** were kept constant, while volume of **B** was doubled, time taken was halved ⇨ rate has doubled. ∴Order of reaction w.r.t. **B** is 1. Comparing Expts 1 & 3, when volumes of **A** and **B** were kept constant, while volume of **Y** was doubled, time taken was halved ⇨ rate has doubled. ∴Order of reaction w.r.t. **Y** is 1. So, rate equation is: rate = k[**B**][**Y**].
✓	3	From option 2, order of reaction w.r.t. **A** is 0. Comparing Expts 4 & 5, since volumes of **B** and **Y** were kept constant, while volume of **A** was halved, time taken should also be halved since rate of decolourisation should remain constant. Hence, the time taken for Expt 5 is 5 s.

14	D
	Concept: Adding inert gas at **constant volume** results in **an increase** in total pressure (due to **increase** in amount of gaseous particles at a constant volume) ⇨ this accounts for the spike observed at **X** as well as the increase in total pressure after **X** for graph **D**. However, partial pressure of each gaseous component **remains unchanged**. Hence, the position of equilibrium **does not shift,** no effect on rate of forward and backward reaction ⇨ this accounts for the second part of graph **D**, after **X**.

15	A	
	Given that: $M(OH)_2(s) + aq \rightleftharpoons M^{2+}(aq) + 2OH^{-}(aq) \quad \Delta H > 0$ When temperature increases, since forward reaction is endothermic, position of equilibrium (POE) will shift to the **right** to absorb the increase in heat.	
✓	1	This statement is correct because an increase in temperature will result in a faster rate of reaction for both directions.
✓	2	Since POE shifts right, there will be a greater amount of OH^{-} ions, hence pH should increase with the increase in basicity.
✓	3	The value of K_{sp} changes when temperature changes. Since POE shifts right, K_{sp} increases.

16	B	
	Concept: At maximum buffer capacity ⇨ for an acidic buffer, [conjugate base] = [acid] and pH = pK_a ⇨ for a basic buffer, [conjugate acid] = [base] and pOH = pK_b	
✗	A	This pair forms a basic buffer. pOH = pK_b ⇨∴pOH = $-\lg(1.78 \times 10^{-5}) = 4.74$ pH = 14 – 4.74 = 9.26
✓	B	This pair forms an acidic buffer, so need to find K_a. $K_a \times K_b = K_w$ $K_a = 10^{-14} \div (2.38 \times 10^{-8})$ $= 4.202 \times 10^{-7}$ mol dm^{-3} ∴pH = pK_a ⇨pH = $-\lg(4.202 \times 10^{-7})$ $= 6.38$
✗	C	This pair forms an acidic buffer, so need to find K_a. $K_a = 10^{-14} \div (1.33 \times 10^{-12})$ $= 0.007519$ mol dm^{-3} ∴pH = pK_a ⇨pH = $-\lg 0.007519$ $= 2.12$
✗	D	This pair forms an acidic buffer, so need to find K_a. $K_a = 10^{-14} \div (5.71 \times 10^{-12})$ $= 0.001751$ mol dm^{-3} ∴pH = pK_a ⇨pH = $-\lg 0.001751$ $= 2.76$

17 **D**

Concept: determine the respective [Ag^+] required to ppt each salt

K_{sp} (Ag_2CrO_4) = $[Ag^+]^2[CrO_4^{2-}]$
$= 1.20 \times 10^{-12}$ mol^3 dm^{-9}
K_{sp} ($AgCl$) = $[Ag^+][Cl^-]$
$= 1.80 \times 10^{-10}$ mol^2 dm^{-6}

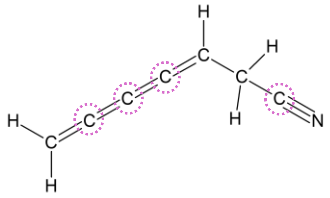
For Ag_2CrO_4:
Minimum [Ag^+] = $\sqrt{(1.20\times10^{-12}) \div 0.20}$
$= 2.45 \times 10^{-6}$ mol dm^{-3}

For Ag*Cl*:
Minimum [Ag^+] = $(1.80 \times 10^{-10}) \div 0.010$
= **1.80×10^{-8} mol dm^{-3}**

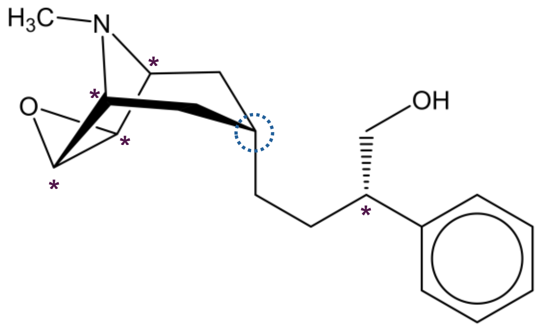
Since minimum [Ag^+] to ppt Ag*Cl*, < [Ag^+] to ppt Ag_2CrO_4, **Ag*Cl* will be ppt out first**.

18 **D**

Solving tip: a sp-hybridised carbon atom is bound to two other atoms via two double bonds or one single and one triple bond.

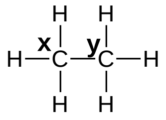


19 **A**



The chiral carbons are marked *.
The circled carbon is achiral as it is bonded to two identical groups (there is an internal plane of symmetry in the ring structure on the left).

20 **C**



There are two carbons in ethane, labelled **x** and **y**.

n =	substitution occurs at	no. of chloroethanes
1	**x**	1
2	**xx,xy**	2
3	**xxx, xxy**	2
4	**xxxy, xxyy**	2
5	**xxxyy**	1
6	**xxxyyy**	1

21 A

Quick solving tip: the first step must involve an addition reaction since the second step is a strong oxidation reaction. The reagent that is suitable incorporates only one -OH group.

✓	**A**	As discussed in quick solving tip.
✗	**B**	Since the reagent used is HBr(g), there is no possibility of incorporating a -OH group.
✗	**C**	H, being a diol, will yield diketo instead of target compound.
✗	**D**	There is no possibility of incorporating a keto group in one step from an alkene.

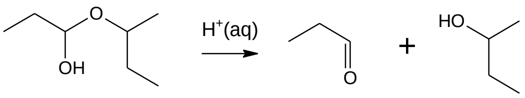
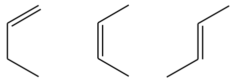
22 **D**

✗	**1**	Both benzene and cyclohexene can react with hydrogen under these drastic conditions, it does not serve as a good distinguishing test as there is no clear colour change.
✓	**2**	Oxidative cleavage of cyclohexene will occur with decolourisation of purple potassium manganate(VII) observed.
✓	**3**	Cyclohexene will decolourise orange aqueous bromine solution but not benzene.

23 **C**

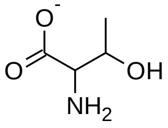
The bond length of C-F bond is shorter than that of C-C*l* bond and it should be a stronger bond. Hence, it is less likely to break to produce fluorine radicals. Options B and D are incorrect.

Option A is incorrect. Fluoroalkanes are more volatile as it has a lower boiling point than chlorofluoroalkanes. The electron cloud size of fluoroalkanes is smaller and less polarisable. Hence, the instantaneous dipole-induced dipole interaction is weaker between fluoroalkanes and therefore require lower amount of energy to overcome the interactions. However, the volatility is not a cause of ozone depletion.

24	**C** Quick solving tip: Note that the left hand side of R bears a three-carbon long chain and that right hand side of R carry a four-carbon chain. This indicates that the hydrolysis happens at the ether oxygen. Using the molecular formula of T, one can deduce that it is a saturated alcohol.  **R** ($C_7H_{16}O_2$) **S** (C_3H_6O) **T** ($C_4H_{10}O$) T undergoes elimination of water (dehydration) to form three different alkenes. 

25	**C** Since all compounds react with 2,4-dinitrophenylhydrazine, all compounds contain carbonyl groups.	
✗	**A**	Compound **X** is not a carbonyl group but an amide.
✗	**B**	Compound **Z** is not a carbonyl group but an ester.
✓	**C**	All compounds contain carbonyl group and compound **Z** will not reduce Ag^+ in Tollens' reagent as it is a ketone.
✗	**D**	All compounds are aldehydes which will cause a reduction of Ag^+ in Tollens' reagent.

26	**B** Only the -COOH group is acidic enough to react with Na_2CO_3(aq) but not the other two phenol groups. Since $2H^+ \equiv CO_3^{2-} \equiv CO_2$, $H^+ \equiv 0.5CO_2$. Hence, no. of mol of CO_2 produced = 0.1 × 0.5 = 0.05. This is equivalent to mass increase of 44 × 0.05 = 2.2 g.

27	**C**	
✓	**1**	Arginine has a higher pI than threonine because the side chain of arginine is more basic than the side chain of threonine resulting in higher pH required for arginine to form a zwitterion.
✗	**2**	At pH = 7, both histidine and arginine carry overall +1 charge as both the amino and side chain remains protonated (pH < pI). Hence, both should migrate to the negatively charged cathode.
✗	**3**	At pH = 7, a larger proportion of threonine exists as single negatively charged as the amino-NH_3^+ group gets progressively deprotonated (because pH > pI). Hence, the predominant species is  .

28	**A** Since the reduction potential of J^+ is more positive than K^{2+}, J^+ is reduced to J while K is oxidised to K^{2+}.	
✓	**1**	$E_{cell}^{\ominus}$ = (+0.80) – (–0.44) = +1.24 V
✓	**2**	Anions from salt bridge will flow in to counter-balance the formation of K^{2+}.
✓	**3**	By LCP, when the concentration of K^{2+} increases, the position of equilibrium will shift to reduce K^{2+} to decrease the concentration of K^{2+}. This will make the reduction potential of K^{2+} more positive and hence, the emf will decrease.

29	**B** Electrode A is positively charged, B is negatively charged, C is positively charged and D is negatively charged. Cu^{2+} is reduced at electrode B while H_2O is preferentially oxidised at electrode C. $S_2O_8^{2-} + 2e^- \rightleftharpoons 2SO_4^{2-}$ $E^{\ominus}$ = +2.01 V $O_2 + 4H^+ + 4e^- \rightleftharpoons 2H_2O$ $E^{\ominus}$ = +1.23 V Since 0.00417 mol of copper is deposited, 0.00834 mol of e^- is required to do so. This same amount of e^- also flowed through to electrode C. Since $O_2 \equiv 4\ e^-$, (0.00834/4) $e^- \equiv 0.002085\ O_2$. Therefore, the volume of O_2 produced at C is 0.002085 × 24 = 0.050 dm^3.

30	**D**	
correct	**A**	P, being a stronger ligand, will displace H_2O as ligand and this causes yellow $[Fe(H_2O)_6]^{3+}$ ions to form a red complex.
correct	**B**	Since **W** is electrically neutral and octahedral, **W** must be [Fe(**P**)$_3$]. To have a coordination number six, **P** must be bidentate.
correct	**C**	
incorrect	**D**	There is no change in oxidation state when a ligand coordinates to a metal ion centre.