Section A

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

1 Pure silicon required for microchips can be manufactured by heating silicon tetrachloride with zinc. 1.27 g of pure silicon could be obtained by heating 8.50 g of impure silicon tetrachloride with an excess of zinc.

What is the percentage of impurity by mass in the sample of silicon tetrachloride?

- **A** 9.56 %
- **B** 14.9 %
- **C** 85.1 %
- **D** 90.4 %
- 2 Two elements **M** and **N** have the following properties:
 - M and N form ionic compounds K₂M and K₂N respectively.
 - Element **N** forms **N**F₆ molecules whereas **M** is not able to do so.

Which pair of electronic configurations of **M** and **N** is correct?

	М	N
Α	[He]2s ² 2p ²	[Ne]3s ² 3p ²
В	[He]2s ² 2p ²	[Ne]3s ² 3p ⁴
С	[He]2s ² 2p ⁴	[Ne]3s ² 3p ²
D	[He]2s ² 2p ⁴	[Ne]3s ² 3p ⁴

- 3 In which of the following pairs does the first species have a larger bond angle than the second?
 - **A** SO₂, PI_3
 - **B** SO_3^{2-}, SO_4^{2-}
 - \mathbf{C} H₂S, NH₃
 - **D** H_2O, H_3O^+

- 4 Which of the following statements is correct?
 - **A** BC l_3 and BrC l_3 have the same molecular shape.
 - **B** Cyclohexene and propanone are non–polar liquids.
 - **C** LiAlH₄ and NaBF₄ contain dative covalent bonds.
 - **D** XeF₄ and $H_2C=C=CH_2$ are planar molecules.
- **5** In which of the following pairs does the first substance have a higher melting point than the second?

	First substance	Second substance
Α	CH ₃ CH ₂ OCH ₃	CH ₃ CH ₂ NHCH ₃
В	$CH_3(CH_2)_4CH_3$	(CH ₃) ₂ CHCH(CH ₃) ₂
С	RbC <i>l</i>	KCl
D	OH OH	ноС,ОН

6 Which of the following correctly shows the arrangement of the ions in decreasing order of ionic radius?

Α	F^{-}	>	0 ²⁻	>	N ^{3–}
в	Ca ²⁺	>	K^{+}	>	Cľ
С	S ²⁻	>	Mg ²⁺	>	Na⁺
D	Se ²⁻	>	Br⁻	>	Ga ³⁺

7 Which graph correctly describes the behaviour of fixed masses of the ideal gases L and M where the number of moles of L is greater than number of moles of M?



8 A student dissolved 10.5 g of sodium fluoride in 250 g of water. The following data is obtained:

Lattice energy of NaF	-918 kJ mol ⁻¹
Enthalpy change of hydration of F ⁻	-457 kJ mol ⁻¹
Enthalpy change of hydration of Na ⁺	-390 kJ mol ⁻¹

Given that the specific heat capacity of water is 4.2 J $g^{-1} K^{-1}$, what would be the final temperature of the solution, if the initial temperature of water is 30 °C?

A 6	6.5 °C	В	13.1 °C	С	16.9 °C	D	46.9 °C
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9 Passing steam over hot coal produces combustible mixture of gases.

 $H_2O(g) + C(s) \implies H_2(g) + CO(g) \quad \Delta H = +131 \text{ kJ mol}^{-1}$

In a certain mixture, the equilibrium partial pressures of steam and hydrogen gas are 90 kPa and 183 kPa respectively.

What will be the new equilibrium partial pressure of hydrogen gas if the new equilibrium partial pressure of steam is increased to 150 kPa?

- A 100 kPa
- B 123 kPa
- C 236 kPa
- **D** 372 kPa
- **10** Paracetamol ($pK_a = 9.5$) is a widely used over-the-counter pain reliever and fever reducer. Its solubility in water is 12.78 mg cm⁻³ at 25 °C. (M_r of Paracetamol = 151.0)



What is its pH in water at 25 °C?

- **A** 0.0846
- **B** 1.07
- **C** 5.29
- **D** 9.50
- 11 The yellow pigment used for road markings is lead(II) chromate, PbCrO₄.

Concentrated lead(II) nitrate is added dropwise to 0.010 mol dm⁻³ potassium chromate(IV). What is the concentration of lead(II) ions when the first trace of precipitate appears? (K_{sp} of PbCrO₄ = 1.69 x 10⁻¹⁴ mol² dm⁻⁶)

- **A** $1.69 \times 10^{-14} \text{ mol dm}^{-3}$
- **B** $1.69 \times 10^{-12} \text{ mol dm}^{-3}$
- **C** 1.30 x 10⁻⁹ mol dm⁻³
- **D** 1.30 x 10^{-7} mol dm⁻³

12 In an experiment, 20 cm³ of a 0.1 mol dm⁻³ solution of a metallic salt reacted exactly with 50 cm³ of 0.1 mol dm⁻³ potassium peroxodisulfate solution. The half-equation for reduction of peroxodisulfate ion is

$$S_2O_8^{2-}(aq) + 2e^- \rightarrow 2SO_4^{2-}(aq)$$

If the original oxidation number of the metal in the salt was +2, what would be the new oxidation number of the metal?

A +1 **B** +3 **C** +5 **D** +7

13 A tiny magnesium electrode which creates an electrical cell with inhaled oxygen could be used in the construction of heart "pacemakers".

From the relevant half-cells:

 $\begin{array}{rll} Mg^{2+} + 2 \ e \end{array} \rightleftharpoons \begin{array}{rl} Mg & E^{e} = -2.38 \ V \\ \frac{1}{2} O_{2} + 2H^{+} + 2e \end{array} \rightleftharpoons \begin{array}{r} H_{2}O & E^{e} = +1.23 \ V \end{array}$

the cell e.m.f. would be 3.61 V under standard conditions. However, in the body a potential of 3.25 V is more usual.

Which of the following gives the best explanation for this lower e.m.f.?

- A the small size of the magnesium electrode
- **B** the low concentration of Mg²⁺ ions surrounding the magnesium electrode
- **C** the high resistance of the body fluids surrounding the electrodes
- **D** the pH of between 7 and 8 of the body fluid surrounding the electrodes
- 14 Which of the following statements about but-1-ene, CH₃CH₂CH=CH₂ is correct?
 - A It exhibits geometric isomerism.
 - **B** It gives a ketone and carbon dioxide on strong oxidation.
 - **C** It gives a chiral compound upon reacting with hydrogen bromide.
 - **D** It reacts with cold dilute potassium manganate(VII) to form butane-2,3-diol.

15 Methylcyclohexane was reacted with limited chlorine in the presence of *uv* light.

Assuming that only mono-chlorination takes place and the reaction occurs at the same rate at all carbon atoms, what is the ratio of the products obtained below?



16 α -Candinene can be found in juniper berries. Compound **Y** is the minor product formed when α -Candinene is reacted with HC*l*.



a-Candinene

How many stereoisomers does Y have?

- **A** 32
- **B** 64
- **C** 128
- **D** 256

17 The equation below represents the reaction between benzene and fuming sulfuric acid (a mixture of sulfur trioxide and sulfuric acid).

$$C_6H_6 + SO_3 \xrightarrow{H_2SO_4} C_6H_5SO_3H$$

What is the role of sulfuric acid?

- **A** a dehydrating agent
- **B** to generate the electrophile
- **C** an oxidising agent
- **D** a nucleophilic reagent
- **18** When (chloromethyl)benzene, $C_6H_5CH_2Cl$, is treated in succession with two reagents **O** and **P**, it gives phenylethanoic acid, $C_6H_5CH_2COOH$.

Which of the following is a possible combination for reagents O and P?

	0	Р
Α	NaOH (aq)	K ₂ Cr ₂ O ₇ (aq)
В	Cl ₂ (aq)	NaOH (aq)
С	NaCN (in aqueous ethanol)	dilute H ₂ SO ₄
D	NaCN with trace of NaOH	dilute HCl

19 Which of the following reagent gives similar results for both butanone and butanal?

- **A** an aqueous solution containing $[Ag(NH_3)_2]^+$
- **B** acidified aqueous potassium dichromate(VI)
- **C** iodine and aqueous sodium hydroxide
- **D** 2,4-dinitrophenylhydrazine

Relative Ease of Reaction: **P** > **Q** > **R**

Which of the following is the correct set of identities of compounds P to R?



21 Compound P can be converted to R in two steps.



Compound P

What are **Q** and **R**?









- 22 Which reagent could be used to separate a mixture of phenylamine and methylbenzene?
 - **A** dilute aqueous sodium hydrogencarbonate
 - B dilute aqueous sodium hydroxide
 - **C** dilute hydrochloric acid
 - D sodium
- **23** Nylon is the world's first synthetic textile polymer. It is developed as a substitute for silk. The following is Nylon 66.



Which of the following statement is false?

- A The functional group present in Nylon 66 is peptide bond.
- **B** It is a condensation polymer.
- **C** It can be hydrolysed to give $HOOC(CH_2)_4COOH$ and $H_2N(CH_2)_6NH_2$.
- **D** It cannot dissolve in water.
- 24 Aspartic acid, HO₂CCH₂CH(NH₂)CO₂H, is an essential amino acid. It can be used to make polymers.



Which of the following statements is true?

- A Reagent A is HBr.
- B Equimolar amounts of hot aqueous KOH and polymer X was used in reaction III.
- **C** The imide (the –CONRCO- group present in polymer **X**) has a higher pK_b value than an amide.
- **D** The values of n and m must be equal.

25 The following mechanism shows the reaction of an alkene with hydrogen azide, HN₃, to form an imine. The four R- groups need not necessarily be the same.



Which of the following statements is false?

- **A** This reaction is catalysed by acid.
- **B** There will be two geometric isomers formed when but-2-ene was used as the original alkene.
- **C** Step **III** is entropy favoured.
- **D** The imine formed cannot exhibit optical isomerism.
- **26** Which of the following is **not** a trend from left to right across the elements of the third period of the Periodic Table?
 - **A** The electronegativity of the atoms increases.
 - **B** The solubility of the oxides of the elements increases steadily.
 - **C** The bonding of the elements changes from metallic to covalent.
 - **D** The aqueous solutions of the chlorides of the elements changes from neutral to acidic.

27 P, **Q** and **R** are Group II elements. The three graphs below show the change in mass when 1.00 g each of $P(IO_3)_2$, $Q(IO_3)_2$ and $R(IO_3)_2$ were heated separately at a temperature of T °C.



Which of the following shows the elements in order of decreasing atomic number?

- **A Q**, **R**, **P**
- B P, R, Q
- **C P**, **Q**, **R**
- D R, Q, P
- **28** 0.03 mol of chlorine gas was bubbled into 100 cm³ of hot aqueous sodium hydroxide of concentration 0.8 mol dm⁻³.

Which of the following statements is **false** regarding the above reaction?

- A 0.01 mol of sodium chlorate(I) was formed.
- **B** 0.01 mol of sodium chlorate(V) was formed.
- **C** The chloride produced required 0.05 mol of silver nitrate for complete precipitation.
- **D** The excess sodium hydroxide required 0.01 mol of dilute sulfuric acid for complete neutralisation.

29 In the laboratory, there are three bottles labelled **X**, **Y** and **Z**. Each bottle contains one of the following reagents: NaC*l* (aq), AgNO₃ (aq) and KI (aq).

The tests were carried out using the reagents in the bottles. The results were summarized in the table below:

Tests	Observations
Mixing of reagent in bottle ${f X}$ with reagent in bottle ${f Y}$	No observable change
Mixing of reagent in bottle X with reagent in bottle Z	Yellow precipitate formed

What are the identities of the reagents in bottle X, Y and Z?

	Х	Y	Z
Α	KI	$AgNO_3$	NaC <i>l</i>
В	NaC <i>l</i>	KI	AgNO₃
С	KI	NaC <i>l</i>	AgNO ₃
D	NaC <i>l</i>	$AgNO_3$	KI

30 When a few drops of NaOH (aq) are added to a solution of Cr(NO₃)₃, a grey-green precipitate is formed. Upon addition of excess NaOH (aq), the precipitate dissolves to form a dark green solution.

A yellow solution is formed, when H_2O_2 (aq) is added to the dark green solution. Upon acidification, the solution becomes orange.

Which of the following statements is **false** regarding this sequence?

- **A** Formation of dative covalent bond
- **B** Oxidation of Cr³⁺ ion
- **C** Precipitation of chromium (III) hydroxide
- **D** The orange solution comprises CrO_4^{2-}

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

A	В	С	D
1, 2 and 3	1 and 2	2 and 3	1 only
are	only are	only are	is
correct	correct	correct	correct

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

31 A certain reversible reaction, **R** (s) + **S** (g) \rightleftharpoons **P** (g) + **Q** (g), gives the following energy profile diagram:



progress of reaction

Which of the following statements are true?

- 1 The forward reaction is more spontaneous at high temperatures.
- **2** The addition of a catalyst lowers E_a but not E'_a since the enthalpy change of reaction, ΔH , decreases.
- **3** The enthalpy change of reaction, ΔH , can be calculated as follows: $\Delta H = \sum (Bonds broken in R \& S) - \sum (Bonds formed in P \& Q)$

32 For this reaction

the rate equation is $2NO + 2H_2 \rightarrow N_2 + 2H_2O$ $Rate = k [NO]^2 [H_2]$

Which of the following mechanisms are consistent with the experimentally obtained results?

1 Step 1 (slow) :
$$2NO + H_2 \rightarrow N_2O + H_2O$$

Step 2 (fast) : $N_2O + H_2 \rightarrow N_2 + H_2O$

- 3 One Step Only : $2NO + 2H_2 \rightarrow N_2 + 2H_2O$
- **33** Hydroxyapatite, $Ca_{10}(PO_4)_6(OH)_2$, is the primary mineral in tooth enamel. Dental cavities are caused when acids dissolve tooth enamel.

$$Ca_{10}(PO_4)_6(OH)_2(s) + 8H^+(aq) = 10Ca^{2+}(aq) + 6HPO_4^{2-}(aq) + 2H_2O(l)$$

Which of the following statements are correct?

- 1 Acids produced from food debris on the tooth surface speeds up tooth decay.
- 2 Dental cavities are formed more readily when the saliva is more acidic.
- **3** Fluoride used in dental treatment replaces OH⁻ in hydroxyapatite with F⁻ and thus helps to slow down tooth decay.
- **34** In the electrolysis of dilute aqueous sodium chloride, what are the correct observations at the two graphite electrodes?

	Negative Electrode	Positive Electrode
1	Hydrogen gas is evolved.	Carbon dioxide gas is also produced.
2	Litmus paper turns blue when dipped in water near electrode.	Litmus paper turns red and finally white when dipped in water near electrode.
3	Hydrogen gas is evolved.	Chlorine gas is evolved.

35 Grignard reagents can be prepared by the reaction of magnesium with a halogenoalkane or halogenoarene, using dry ether as the solvent:

$$R - CH_2 - X + Mg \rightarrow R - CH_2 - MgX \qquad X = Cl \text{ or } Br$$

The carbon-magnesium bonds in Grignard reagents are highly polar. This property makes the Grignard reagent very useful in organic synthesis as it can react with other polar organic molecules to form a carbon-carbon bond. An example of a Grignard reagent reacting with a ketone to form an alcohol via a two stage process is given below:



Which of the following statements are true?

- **1** Stage 1 is nucleophilic addition.
- 2 Stage 2 is hydrolysis.
- **3** CH₃CH₂CH(OH)CH₃ can be produced when CH₃CH₂MgBr reacts with CH₃CHO and then treated with water.
- **36** 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) is a carcinogen. TCDD was the main ingredient in Agent Orange, a herbicide used in the Vietnam War.

TCDD can be made by reacting 2,4,5-trichlorophenol with KOH.



2,4,5-trichlorophenol

2,3,7,8-tetrachlorodibenzo-p-dioxin

Which of the following statements are correct?

- 1 The reaction involves nucleophilic substitution.
- 2 The KOH is used to deprotonate the phenol and the resulting species which functions as a base in the next step.
- **3** It is possible to form a tricyclic isomer of TCDD by reacting KOH and 3,4,5-trichlorophenol.

37 Cyclen is often used as a ligand to selectively bind cations in medical imaging. It is commonly made through the following route:



Which of the following statements about cyclen are correct?

- 1 Step I is a condensation reaction.
- 2 Step III involves the reduction of X.
- **3** Cyclen can function as a tetradentate ligand under low pH conditions.
- **38** The Darzens condensation is an interesting reaction that converts a carbonyl into another carbonyl.

The general scheme of the Darzens condensation is shown below:



Which of the following compound(s) can be synthesised from the corresponding carbonyl and ester?

	carbonyl reactant	ester	product
1	(CH ₃) ₂ CHCHO	ClCH ₂ CO ₂ CH ₂ CH ₃	(CH ₃) ₂ CHCH ₂ CHO
2	$C_6H_5COCH_3$	ClCH ₂ CO ₂ CH ₂ CH ₃	C ₆ H ₅ CH ₂ CH ₂ CHO
3	НСНО	CH ₃ CH ₂ CHC/CO ₂ CH ₂ CH ₃	CH ₃ COCH ₃

39 The graph below shows the variation in the second ionisation energies for the consecutive elements **Q** to **Z** in the Periodic Table, all with proton number below 20.



What can be deduced from the above?

- 1 Effervescence is observed when a magnesium strip is dipped into the aqueous solution containing the chloride of element **X**.
- 2 Upon dissolving oxide of element **U** in water, followed by reacting with oxide of element **W**, the solution obtained is approximately neutral.
- **3 Q** has a smaller ionic radius than **R**.
- **40** Compared to s-block elements, transition elements generally exhibit the following properties:
 - Smaller atomic radius
 - Very high melting point
 - Larger first ionisation energy
 - Better electrical conductivity

Which of the following statements account for the observed properties?

- 1 Presence of 3d electrons which provide poor shielding for the 4s electrons
- 2 Presence of 3d and 4s electrons for formation of strong metallic bonds
- 3 Stronger nuclear attraction for valence electrons as atomic number increases