5

CHEMISTRY

9729/01

Paper 1 Multiple Choice

23 September 2021

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, civics group and registration number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in this question paper.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **10** printed pages.

[Turn Over

1   Which electronic configuration represents an atom of an element, at ground state, that forms a stable ion with a charge of +3?

A $1s^2 2s^2 2p^3$

B $1s^2 2s^2 2p^6 3s^2 3p^1$

C $1s^2 2s^2 2p^6 3s^2 3p^6$

D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2 4s^1$

2   Which particle has more protons than electrons and more protons than neutrons?

$$\left(D = {}^2_1H\right)$$

A H_3O^+ B D_3O^+ C D_2O D OH^-

3   Gaseous particle **R** has a proton number n and forms a stable monoatomic ion of charge -1.

Gaseous particle **S** has a proton number of $(n+2)$ and it forms a stable monoatomic ion which is isoelectronic with the ion of **R**.

Which of the following statement is correct?

A   Ion of **S** has a smaller ionic radius than ion of **R**.

B   Ion of **R** releases more energy than ion of **S** when an electron is added to each particle.

C   **R** has a larger atomic radius than **S**.

D   Ion of **S** requires less energy than ion of **R** when an electron is removed from each particle.

4   In a single covalent bond, one pair of electrons is shared by two atoms. Which of the following statement is true for **all** single covalent bonds?

A   Covalent bonds are formed when bonding electrons are shared equally between two atoms.

B   Covalent bonds allow the atoms involved to complete their outer electron shell configuration.

C   Covalent bonds formed between atoms of different electronegativities are stronger.

D   Covalent C–H bonds formed between sp^3 hybridised C and H atoms are weaker than that formed between sp^2 hybridised C and H atoms.

5   Cinnamaldehyde occurs naturally in cinnamon oil.
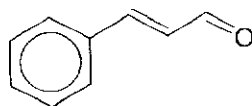
Which of the following statements are true about the structure?

1   Hydrogen bonds can be formed between cinnamaldehyde molecules.

2   Cinnamaldehyde dissolves in organic solvents readily via instantaneous dipole–induced dipole interactions.

3   The bond angles about all carbon atoms in cinnamaldehyde are the same.

A 1, 2 and 3   **B** 2 and 3   **C** 3 only   **D** none of the above

6   Which of the following statements about Group 17 elements is true?

A I_2 can reduce $S_2O_3^{2-}$ to $S_4O_6^{2-}$.

B   When $Br_2(g)$ is bubbled into $NaCl(aq)$, an orange solution is produced.

C Cl_2 is soluble in water as it can form favourable hydrogen bonds with water.

D F_2 is more volatile than Br_2 as the F–F bonds are weaker than the Br–Br bonds.

7   Which of the following pairs of reactants **cannot** undergo an acid-base reaction together?

A NH_3 and H_2O

B NH_3 and BH_3

C $AlCl_3$ and Cl_2

D $AlCl_3$ and BH_3

8   Which of the following quantities is equal to the Avogadro constant?

A   The number of atoms in 24 dm^3 of oxygen under room temperature and pressure.

B   The number of molecules in 1 dm^3 of chlorine at 273 K and 1.5 atm.

C   The number of ions in 68.05 g of $CaSO_4$.

D   The number of carbon atoms in 22.7 dm^3 of ethane gas under standard temperature and pressure.

27 *Use of the Data Booklet is relevant to this question.*

A galvanic cell is made up of an Ag^+/Ag half-cell and a Fe^{3+}/Fe^{2+} half-cell.

Which of the following statements are correct?

 1 Addition of solid potassium iodide to the Ag^+/Ag half-cell results in a more positive value for the reduction potential of Ag^+/Ag half-cell.

 2 Addition of water to the Ag^+/Ag half-cell has no effect on the cell e.m.f.

 3 Addition of water to the Fe^{3+}/Fe^{2+} half-cell has no effect on the cell e.m.f.

 A 1 and 2   B 1 and 3   C 3 only   D 1, 2 and 3

28 *Use of the Data Booklet is relevant to this question.*

A current of 15.0 A flow through a saturated solution of sodium chloride for 30 minutes. Which of these statements describe the reaction at the anode during this time?

 A 1.12×10^{-3} mol of oxygen gas is produced.

 B 6.99×10^{-2} mol of oxygen gas is produced.

 C 5.60×10^{-3} mol of chlorine gas is produced.

 D 1.40×10^{-1} mol of chlorine gas is produced.

29 Which statement correctly defines a transition element?

 A Transition elements exhibit more than one oxidation state in their compounds.

 B Transition elements form many coloured compounds.

 C Transition elements have partially filled d orbitals.

 D Transition elements or their compounds are widely used as catalysts.

30 When copper(II) sulfate is dissolved in water it gives a blue solution. When this solution is treated with an excess of concentrated hydrochloric acid, it turns yellow.
What are the formulae of the copper species in the blue and yellow solutions?

	blue	yellow
A	$CuSO_4$	$CuCl_2$
B	$CuSO_4(H_2O)_4$	$[CuCl_6]^{4-}$
C	$[Cu(H_2O)_6]^{2+}$	$[CuCl_4]^{2-}$
D	Cu^{2+}	$[CuCl_6]^{3-}$

1 A× $1s^2\,2s^2\,2p^3 \rightarrow 1s^2\,2s^2$ (not octet)

   B✓ $1s^2\,2s^2\,2p^6\,3s^2\,3p^1 \rightarrow 1s^2\,2s^2\,2p^6$ (octet)

   C× $1s^2\,2s^2\,2p^6\,3s^2\,3p^6 \rightarrow 1s^2\,2s^2\,2p^6\,3s^2\,3p^3$ (not octet)

   D× [Ar] $3d^2\,4s^1$ (not ground state; ground state is [Ar] $3d^1\,4s^2$) → [Ar] (octet)

   $\Rightarrow$ **B**

2

	$^{1}_{1}H_{3}\,^{16}_{8}O^{-}$	$^{2}_{1}H_{3}\,^{16}_{8}O^{-}$	$^{2}_{1}H_{2}\,^{16}_{8}O$	$^{16}_{8}O_{1}^{1}H^{-}$
p	$1\times3+8$ $=11$	$1\times3+8$ $=11$	$1\times2+8$ $=10$	$8+1$ $=9$
e	$1\times3+8-1$ $=10$	$1\times3+8-1$ $=10$	$1\times2+8$ $=10$	$8+1+1$ $=10$
n	$0\times3+8$ $=8$	$1\times3+8$ $=11$	$1\times2+8$ $=10$	$8+0$ $=8$

   $\Rightarrow$ **A**

3 $_nR$ gains 1 electron to form stable $_nR^-$, which has $(n+1)$ electrons
   $\Rightarrow$ **R** is in Group 17.

   $_{n+2}S$ forms a stable ion which is isoelectronic with $_nR^-$. Hence $_{n+2}S$ must have **lost** 1 electron, to form $_{n+2}S^+$, which has $(n+2)-1 = (n+1)$ electrons
   $\Rightarrow$ **S** is in Group 1 of the *next period*.

   A✓ Since $_nR^-$ and $_{n+2}S^+$ are iso-electronic, $_{n+2}S^+$ with a higher nuclear charge will have a smaller ionic radius as the effective nuclear charge experienced by the valence e^-s is higher.

   B× $_nR^- + e^- \rightarrow {}_nR^{2-}$ will be endothermic due to repulsion of the incoming e^-; $_{n+2}S^+ + e^- \rightarrow {}_{n+2}S$ will be exothermic due to attraction of the incoming e^-.

   C× As **S** is an element in the next period, with one additional filled principal quantum shell, **S** has a larger atomic radius despite the higher nuclear charge.

   D× $_{n+2}S^+ - e^- \rightarrow {}_{n+2}S^{2+}$ will be more endothermic than $_nR^- - e^- \rightarrow {}_nR$ since the e^- is being removed from positively charged $_{n-2}S^-$.

   $\Rightarrow$ **A**

4 A× Polar single covalent bonds involves unequal sharing of bonding electrons.
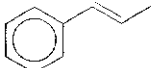
   B× Single covalent bonds are also formed in atoms without a complete octet, *e.g.* BF_3 with 6 outer shell electrons around B, or with an expanded octet, *e.g.* PF_5 with 10 outer shell electrons around P.

   C× H–H bond (436 kJ mol^{-1}) is stronger than H–Cl bond (431 kJ mol^{-1})

   D✓ Due to the larger s-character of sp^2 hybridised C (33%) compared to sp^3 hybridised C (25%), the bonding electrons are closer to the nucleus (s orbitals are closer to nucleus than p orbitals). Hence, the C_{sp^2}–H bond is stronger than a C_{sp^3}–H bond.

   $\Rightarrow$ **D**

5 1× There are no H bonded to F, O or N in cinnamaldehyde $\Rightarrow$ no H bonds between cinnamaldehyde molecules.

   2✓ The non-polar [structure] chain of cinnamaldehyde can form strong instantaneous dipole-induced dipole solvent-solute interactions with the non-polar hydrocarbon parts of organic solvents.

   3✓ All carbon atoms in cinnamaldehyde are sp^2 hybridised, thus all the bond angles are the same at 120°.

   $\Rightarrow$ **B**

6 A× $S_2O_3^{2-}$ to $S_4O_6^{2-}$ is an oxidation as the oxidation number of S increases from +2 to +2.5.

   B✓ Br_2 is unable to oxidise Cl^-. Hence $Br_2(g)$ dissolves in water to give orange $Br_2(aq)$.

   C× Although Cl_2 molecules possess lone pairs on Cl. However, Cl is not sufficiently electronegative (F, O or N) to form H bonds with the H in water.

   D× Volatility is related to the ease to vaporisation, which has to do with overcoming intermolecular forces of attraction, and not breaking of covalent bonds.

   $\Rightarrow$ **B**

7 A✓ $NH_3 + H_2O \rightleftharpoons NH_4^+ + OH^-$ (Brønsted-Lowry acid-base reaction)

   B✓ $NH_3 + BH_3 \rightarrow H_3N{\rightarrow}BH_3$ (Lewis acid-base reaction)

   C✓ $AlCl_3 + Cl_2 \rightleftharpoons [Cl{\rightarrow}AlCl_3]^- + Cl^+$ (Lewis acid-base reaction)

   D× Both $AlCl_3$ and BH_3 are electron-deficient species, capable of acting as Lewis acids only.

   $\Rightarrow$ **D**

8 A× $n_{O_2} = \dfrac{24\ dm^3}{24\ dm^3\ mol^{-1}} = 1\ mol$

   no. of O atoms $= 1\ mol \times 2 \times N_A = 2N_A$

   B× $n_{Cl_2} = \dfrac{(1.5\times101325)\times(1\times10^{-3})}{8.31\times273}$
   $= 0.0670\ mol$

   no. of Cl_2 molecules $= 0.670\ mol \times N_A$
   $= 0.670N_A$

   C✓ $n_{CaSO_4} = \dfrac{68.05}{40.1+32.1+16.0\times4}$
   $= 0.500\ mol$

   $CaSO_4 \rightarrow Ca^{2+} + SO_4^{2-}$

   no. of ions $= 0.500\ mol \times 2 \times N_A = 1.00N_A$

   D× $n_{C_2H_4} = \dfrac{22.7\ dm^3}{22.7\ dm^3\ mol^{-1}} = 1\ mol$

   no. of C atoms $= 1\ mol \times 2 \times N_A = 2N_A$

   $\Rightarrow$ **C**

9 pH of the period 3 chloride in water:
   no hydrolysis   – $NaCl$: 7
   slightly hydrolysis   – $MgCl_2$: 6.5
   extensive hydrolysis – $AlCl_3$: 3
   complete hydrolysis – $SiCl_4$, PCl_5 : 2

   $\Rightarrow$ **C**

10 A× 6 P–P bonds are broken. So
   $\Delta H_r = \dfrac{1}{4}(6\times B.E.(P–P)) = \dfrac{3}{2}B.E.(P–P)$

   B✓ Phosphorus exists as $P_4(s)$ under standard condition.

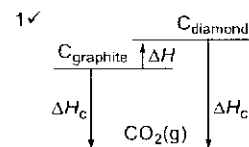   C× Phosphorus exists as $P_4(s)$ under standard condition.

   D× Enthalpy change of vapourisation is the energy required to transform one mole of a liquid substance into its gases state: $P_4(l) \rightarrow P_4(g)$

   $\Rightarrow$ **B**

11 $\Delta H = \Delta G + T\Delta S = +3.08 + 298 \times \dfrac{-3.3}{1000}$
   $= +2.10\ kJ\ mol^{-1}$

   1✓
   [diagram: energy cycle with $C_{graphite}$, $C_{diamond}$, ΔH, ΔH_c, $CO_2(g)$]

   2× Graphite is more stable than diamond. C–C bonds in graphite are stronger than in diamond.

   3× Since ΔS is negative, $-T\Delta S$ is always positive. Hence ΔG increases (less spontaneous) with temperature.

   $\Rightarrow$ **A**

12 Since $[A] \ll [B]$,
   rate $= k'[A]$, where $k' = k[B]$
   $t_\frac{1}{2} = \dfrac{\ln 2}{k'} = \dfrac{\ln 2}{k[B]}$

   When [B] is doubled, $t_\frac{1}{2}$ will be halved.

   $\Rightarrow$ **B**

13 1✓ Enzymes provide an alternative pathway with a lower activation energy.

   2✓ When [substrate] is low, there are available active sites for additional substrate molecules to bind to. Hence, rate $\propto$ [substrate].

   3× When [substrate] is high, all active sites are occupied. No available active sites for additional substrate molecules to bind to. Hence rate is constant.

   $\Rightarrow$ **B**

14 Given $K_c = \dfrac{[C]^2}{[A]^2[B]} = x$

   For the new equilibrium,

   $K_c' = \dfrac{[A][B]^\frac{1}{2}}{[C]} = \dfrac{1}{\dfrac{[C]}{[A][B]^\frac{1}{2}}} = \dfrac{1}{\left(\dfrac{[C]^2}{[A]^2[B]}\right)^{\frac{1}{2}}} = \dfrac{1}{\sqrt{x}}$

   $\Rightarrow$ **C**

15 1✓ $\downarrow$ing the volume $\uparrow$es the concentration of the reactants and products, leading to $\uparrow$ in rates of both the forward and backward reactions.
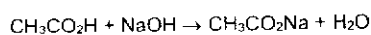
   2× adding a noble gas at constant pressure will $\downarrow$ the partial pressure of all components $\Rightarrow$ eqm shifts to the side with more gaseous particles.

   3× Equilibrium constants are only affected by changes in temperature.

   $\Rightarrow$ **D**

16 $n_{NaOH} = \dfrac{20}{1000} \times 0.500 = 0.0100$ mol

$n_{CH_3CO_2H} = \dfrac{20}{1000} \times 1.00 = 0.0200$ mol

$CH_3CO_2H + NaOH \rightarrow CH_3CO_2Na + H_2O$

$[CH_3CO_2H] = \dfrac{0.0200 - 0.0100}{\dfrac{20+20}{1000}} = 0.250$ mol dm^{-3}

$[CH_3CO_2Na] = \dfrac{0.0100}{\dfrac{20+20}{1000}} = 0.250$ mol dm^{-3}

$pH = pK_a + \lg\dfrac{[CH_3CO_2Na]}{[CH_3CO_2H]} = -\lg(1.8 \times 10^{-5}) = 4.74$

$\Rightarrow$ **C**

17 Given solubility of AgCl and AgBr are x and y mol dm^{-3} respectively,

$K_{sp}(AgCl) = [Ag^+][Cl^-] = x^2$ mol^2 dm^{-6}
$K_{sp}(AgBr) = [Ag^+][Br^-] = y^2$ mol^2 dm^{-6}

In a solution saturated with **both** AgCl and AgBr, let the solubility of AgCl and AgBr be x' and y' mol dm^{-3} respectively.

$[Ag^+] = x' + y'$, $[Cl^-] = x'$, $[Br^-] = y'$

$K_{sp}(AgCl) = [Ag^+][Cl^-] = (x'+y')(x') = x^2$
$K_{sp}(AgBr) = [Ag^+][Br^-] = (x'+y')(y') = y^2$

1✗ $(x'+y')(x') + (x'+y')(y') = x^2 + y^2$
$(x'+y')^2 = x^2 + y^2$

$[Ag^+] = x' + y' = \sqrt{x^2 + y^2} < x + y$

2✓ $[Br^-] = y' = \dfrac{y^2}{x'+y'} = \dfrac{y^2}{\sqrt{x^2+y^2}} < y$

3✓ $[Ag^+] = x' + y' = [Cl^-] + [Br^-]$

$\Rightarrow$ **D**

18 A✗ There are no chiral centres in 2-methyl-N-phenylpropan-1-imine.

B✗ π bonds are formed by side-on overlap of unhybridised p orbitals. The C–N σ bond is formed by head-on overlap between sp^2 hybrid orbitals of C and N.

C✗ N forms 2 σ bonds and possesses 1 lone pair. Hence it is sp^2 hybridised.

D✓ The lone pair on N in 2-methyl-N-phenylpropan-1-imine is in a sp^2 hybrid orbital, while that in NH$_3$ is in a sp^3 hybrid orbital. Due to the larger s-character of sp^2 hybrid orbital (33%) compared to sp^3 hybrid orbital (25%), the lone pair is closer to the nucleus (s orbitals are closer to nucleus than p orbitals) and less available for donation.
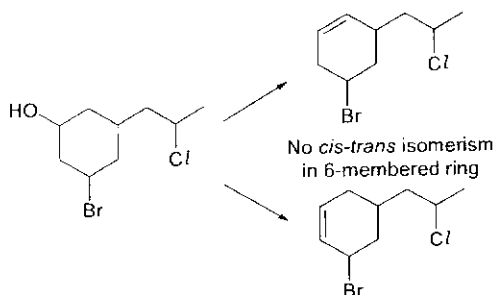
$\Rightarrow$ **D**

19 A✓
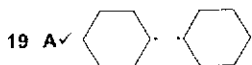
B✗
• (2 C fragment needed)

C✓

20

D✓
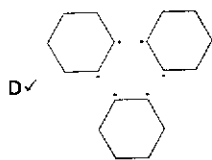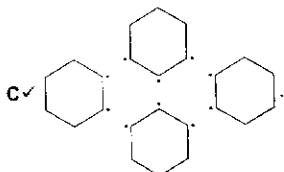
$\Rightarrow$ **B**

20 Dehydration upon heating with conc. H_2SO_4,

No cis-trans isomerism in 6-membered ring

$\Rightarrow$ **A**

21 A✗ The alkyl group is an activating group. Hence alkylbenzene will react faster.

B✓ Anhydrous AlX$_3$ and FeX$_3$ can be used in Friedel-Crafts alkylation to generate the carbocation.

C✓ Due to the bulky alkyl group, the 2-position is sterically hindered and hence the CH$_3$CO– group will preferentially go to the 4-position.

D✓ It is an electrophilic substitution:
Ar–H + RCOCl $\rightarrow$ Ar–COR + HCl

$\Rightarrow$ **A**

22 ⬡—X and (structure)—X are resistant to nucleophilic substitution as the lone pair of electrons on X is delocalised into the benzene ring and C=C respectively, imparting partial double bond in the C–X bond, making cleavage difficult.

Among the (structure)–X, the C–I bond being the weakest means that (structure)–I react the fastest and should give a ppt.

As the acyl carbon in (structure with O and Br) is attached highly electronegative O besides Br, it is the most electron-deficient, and hence react the fastest, giving the most ppt.

$\Rightarrow$ **A**
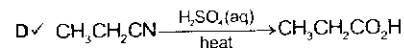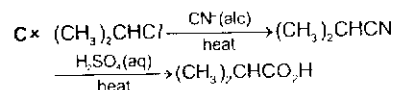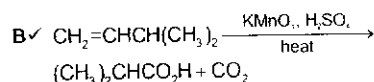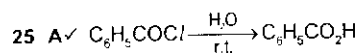
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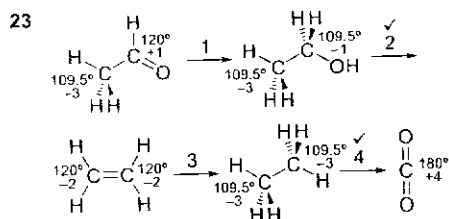
$\Rightarrow$ **B**

24 Since heptan-2-one is formed from **W** via oxidation with acidified K$_2$Cr$_2$O$_7$, **W** must be the secondary alcohol, heptan-2-ol.

Heptan-2-one can be reduced back to heptan-2-ol using NaBH$_4$, LiAlH$_4$ or H$_2$.

Iodoform reaction on the methyl ketone, heptan-2-one leads to lost of the methyl carbon as CHI$_3$, resulting in a step-down reaction to give 6-carbon hexanoic acid.

$\Rightarrow$ **D**

25 A✓ $C_6H_5COCl \xrightarrow[r.t.]{H_2O} C_6H_5CO_2H$

B✓ $CH_2=CHCH(CH_3)_2 \xrightarrow[heat]{KMnO_4, H_2SO_4}$
$(CH_3)_2CHCO_2H + CO_2$

C✗ $(CH_3)_2CHCl \xrightarrow[heat]{CN^- (alc)} (CH_3)_2CHCN$
$\xrightarrow[heat]{H_2SO_4(aq)} (CH_3)_2CHCO_2H$

D✓ $CH_3CH_2CN \xrightarrow[heat]{H_2SO_4(aq)} CH_3CH_2CO_2H$

$\Rightarrow$ **C**

26 **Z** is a 3° amide which can only be made from an acyl chloride and a 2° amine:

2° amine + acyl chloride $\rightarrow$ 3° amide + HCl
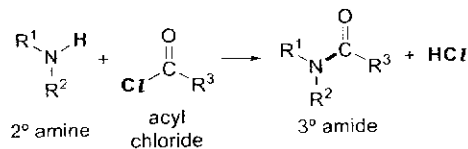
$\Rightarrow$ **A**

27 [R]: $E^{\ominus}(Ag^+|Ag) = +0.80$ V
[O]: $E^{\ominus}(Fe^{3+}|Fe^{2+}) = +0.77$ V

$E_{cell} = E(Ag^+|Ag) - E(Fe^{3+}|Fe^{2+})$

1✗ Addition of KI(aq), ppt AgI(s), causing [Ag$^+$] to $\downarrow$
$\Rightarrow Ag^+ + e^- \rightleftharpoons$ Ag shifts left
$\Rightarrow E(Ag^+|Ag) < E^{\ominus}(Ag^+|Ag)$
$\Rightarrow E_{cell} < E^{\ominus}_{cell}$

2✗ Addition of H$_2$O to Ag$^+$/Ag half-cell causes [Ag$^+$] to $\downarrow$
$\Rightarrow Ag^+ + e^- \rightleftharpoons$ Ag shifts left
$\Rightarrow E(Ag^+|Ag) < E^{\ominus}(Ag^+|Ag)$
$\Rightarrow E_{cell} < E^{\ominus}_{cell}$

3✓ Addition of H$_2$O to Fe^{3+}/Fe^{2+} half-cell causes [Fe^{3+}] and [Fe^{2+}] to $\downarrow$ by the same extent.
$\Rightarrow Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$ is not affected
$\Rightarrow E(Fe^{3+}|Fe^{2+}) = E^{\ominus}(Fe^{3+}|Fe^{2+})$
$\Rightarrow E_{cell}$ is not affected

$\Rightarrow$ **C**

28 Electrolysis of saturated NaCl leads to the discharge of Cl$_2$ at the anode:

$2Cl^- \rightarrow Cl_2 + 2e^-$
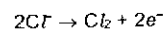
$Q = I \times t = 15.0 \times 30 \times 60 = 27000$ C

$n_e = \dfrac{Q}{F} = \dfrac{27000}{96500} = 0.2798$ mol

$n_{Cl_2} = \dfrac{1}{2} n_e = 0.1399$ mol

$\Rightarrow$ **D**

Answer Key

Qn	Ans	Qn	Ans	Qn	Ans
1	B	11	A	21	A
2	A	12	B	22	A
3	A	13	B	23	B
4	D	14	C	24	D
5	B	15	D	25	C
6	B	16	C	26	A
7	D	17	D	27	C
8	C	18	D	28	D
9	C	19	B	29	
10	B	20	A	30	