22126113

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

CHEMISTRY
HIGHER LEVEL
PAPER 1

Tuesday 8 May 2012 (afternoon)

1 hour

INSTRUCTIONS TO CANDIDATES

• Do not open this examination paper until instructed to do so.
• Answer all the questions.
• For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
• The periodic table is provided for reference on page 2 of this examination paper.
• The maximum mark for this examination paper is *[40 marks]*.

The Periodic Table

Key:

Atomic number	
Element	
Relative atomic mass	

1	2	3	4	5	6	7	0
1 **H** 1.01							2 **He** 4.00
3 **Li** 6.94	4 **Be** 9.01	5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95

1	2												3	4	5	6	7	0
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.71	29 **Cu** 63.55	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** 98.91	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.30
55 **Cs** 132.91	56 **Ba** 137.34	57 † **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.85	75 **Re** 186.21	76 **Os** 190.21	77 **Ir** 192.22	78 **Pt** 195.09	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.19	83 **Bi** 208.98	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ‡ **Ac** (227)															

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** 146.92	62 **Sm** 150.35	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.92	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

1. What is the total number of atoms in 0.100 mol of $[Pt(NH_3)_2Cl_2]$?

    A.   11

    B. 6.02×10^{22}

    C. 3.01×10^{23}

    D. 6.62×10^{23}

2. Nitroglycerine, $C_3H_5N_3O_9$, can be used in the manufacture of explosives. What is the coefficient of $C_3H_5N_3O_9(l)$ when the equation for its decomposition reaction is balanced using the lowest whole numbers?

$$\underline{\quad} C_3H_5N_3O_9(l) \rightarrow \underline{\quad} CO_2(g) + \underline{\quad} H_2O(l) + \underline{\quad} N_2(g) + \underline{\quad} O_2(g)$$

    A.   2

    B.   4

    C.   20

    D.   33

3. The volume occupied by one mole of an ideal gas at 273 K and 1.01×10^5 Pa is 22.4 dm^3. What volume, in dm^3, is occupied by 3.20 g $O_2(g)$ at 273 K and 1.01×10^5 Pa?

    A.   2.24

    B.   4.48

    C.   22.4

    D.   71.7

4.   What volume, in m^3, is occupied by 2.00 mol of gas at $27\,^\circ C$ and 2.00 atm pressure?
Assume: $1.00\ atm = 1.01 \times 10^5$ Pa and $R = 8.31\ J\ K^{-1}\ mol^{-1}$.

A. $\dfrac{8.31 \times 27}{1.01 \times 10^5}$

B. $\dfrac{2.00 \times 8.31 \times 27}{1.01 \times 10^5}$

C. $\dfrac{2.00 \times 8.31 \times 300}{2.00 \times 1.01 \times 10^5}$

D. $\dfrac{2.00 \times 8.31 \times 300}{1.01 \times 10^5}$

5.   In the electromagnetic spectrum, which will have the shortest wavelength **and** the greatest energy?

	Shortest wavelength	Greatest energy
A.	ultraviolet	ultraviolet
B.	infrared	infrared
C.	ultraviolet	infrared
D.	infrared	ultraviolet

6.   What is the electron configuration of Sn^{2+}?

A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^2$

B. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}$

C. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 4d^{10}\ 5p^2$

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^8\ 5p^2$

7. Which series is correctly arranged in order of **decreasing** radius?

A. $Al^{3+} > Mg^{2+} > Na^+ > F^-$

B. $F^- > Na^+ > Mg^{2+} > Al^{3+}$

C. $F^- > Al^{3+} > Mg^{2+} > Na^+$

D. $Na^+ > Mg^{2+} > Al^{3+} > F^-$

8. Which complex is colourless in solution?

A. $[Fe(H_2O)_6]Cl_2$

B. $[Ni(NH_3)_6]Cl_2$

C. $[Zn(H_2O)_6](NO_3)_2$

D. $K_3[Co(CN)_6]$

9. Which species contain dative covalent bonds?
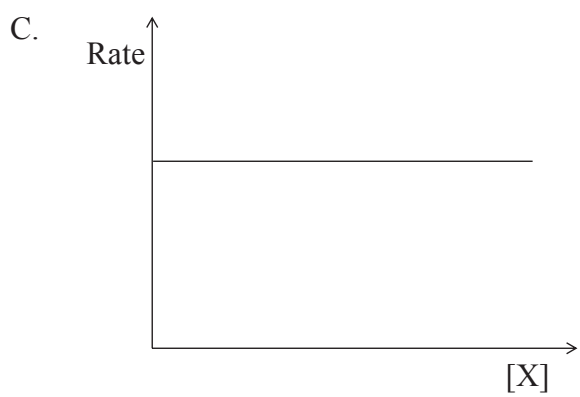
    I. CO

    II. NH_3

    III. H_3O^+

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

10. Which single covalent bond is the most polar, given the following electronegativity values?

Element	H	C	S	O
Electronegativity	2.2	2.6	2.6	3.4

A.   C–O

B.   S–H

C.   C–H

D.   O–H

11. The Lewis (electron dot) structure of paracetamol (acetaminophen) is:
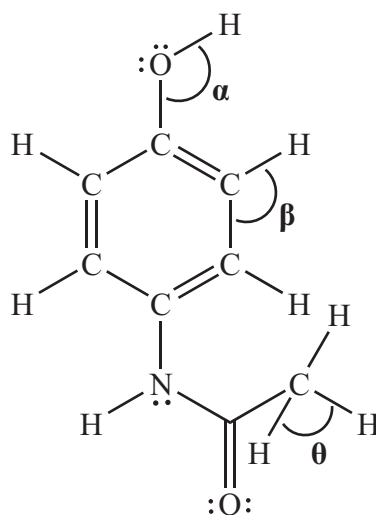
What are the approximate values of the bond angles?

	α	β	θ
A.	104.5°	120°	109.5°
B.	109.5°	109.5°	109.5°
C.	120°	120°	90°
D.	104.5°	120°	90°

12. Which types of intermolecular forces exist in HBr, Cl_2 and CH_3F?

	HBr	**Cl$_2$**	**CH$_3$F**
A.	van der Waals' and dipole-dipole	van der Waals' only	van der Waals' and dipole-dipole
B.	van der Waals' and dipole-dipole	van der Waals' only	van der Waals', dipole-dipole and hydrogen bonding
C.	van der Waals' only	van der Waals' only	van der Waals', dipole-dipole and hydrogen bonding
D.	van der Waals' and dipole-dipole	van der Waals' and dipole-dipole	van der Waals', dipole-dipole and hydrogen bonding

13. Retinol (vitamin A) contains a total of **5** double bonds and **46** single bonds.
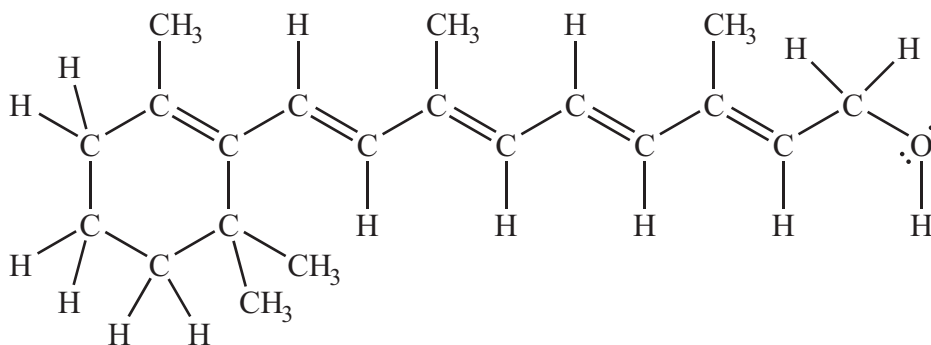
Which statements are correct?

    I.   There are 51 σ and 5 π bonds.

    II.   The oxygen atom is sp^3 hybridized.

    III.   Retinol is a primary alcohol.

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

14. Zinc metal contains metallic bonding. Which is the best description of a metallic bond?

   A.   The electrostatic attraction between a pair of electrons and positively charged nuclei.

   B.   The electrostatic attraction between oppositely charged ions.

   C.   The electrostatic attraction between a lattice of positive ions and delocalized electrons.

   D.   The bond formed when one atom provides both electrons in a shared pair.

15. Which reactions are exothermic?

   I. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$
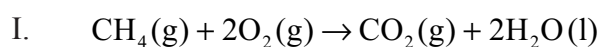
   II.   Reaction of aspirin with sodium hydroxide

Aspirin

   III. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
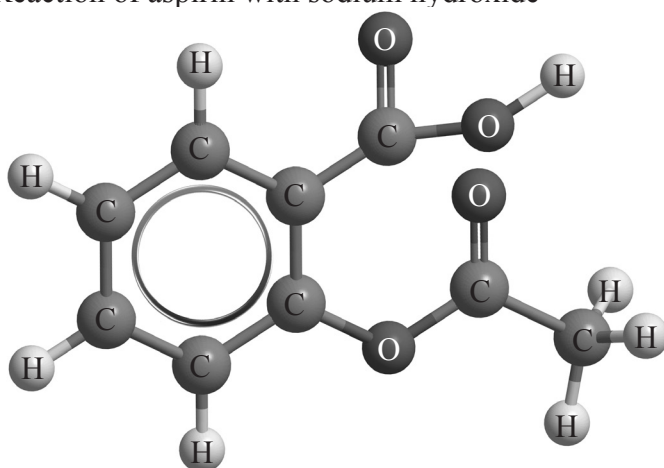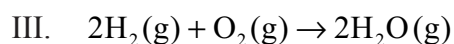
   A.   I and II only

   B.   I and III only

   C.   II and III only

   D.   I, II and III

16. Which equation represents the electron affinity of chlorine?

    A. $Cl(g) + e^- \rightarrow Cl^-(g)$

    B. $Cl(g) + e^- \rightarrow Cl\bullet(g)$

    C. $Cl_2(g) + 2e^- \rightarrow 2Cl^-(g)$

    D. $Cl(g) \rightarrow Cl^+(g) + e^-$

17. During which process is there a **decrease** in the entropy of the system?

    A. $Ag(s) + 2H^+(aq) + NO_3^-(aq) \rightarrow Ag^+(aq) + H_2O(l) + NO_2(g)$

    B. $Ba(OH)_2(s) \rightarrow BaO(s) + H_2O(g)$

    C. $PCl_3(g) + Cl_2(g) \rightarrow PCl_5(g)$

    D. $H_2O(s) \rightarrow H_2O(l)$

18. Which are appropriate units for the rate of a reaction?

    A. $mol\,dm^{-3}\,s^{-1}$

    B. $mol\,dm^{-3}\,s$

    C. $mol\,dm^{-3}$

    D. s

19. Which graph represents a reaction that is second order with respect to X for the reaction X → products?

A.

[X] vs Time

B.

[X] vs Time

C.

Rate vs [X]

D.

[X] vs Time
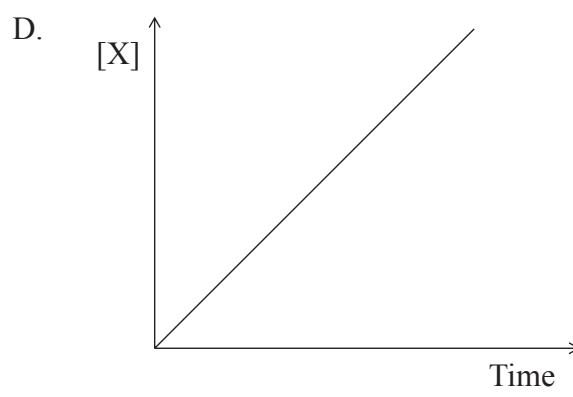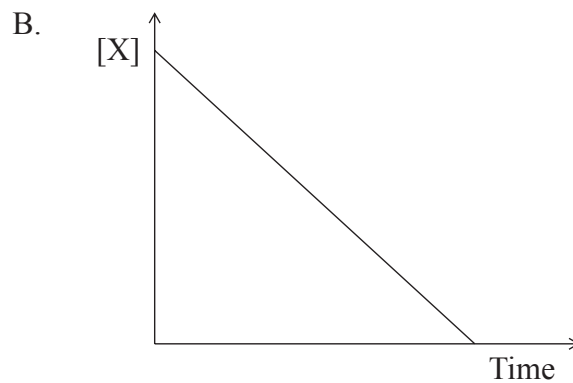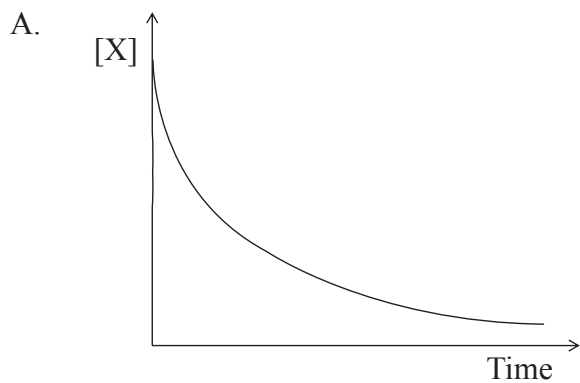
20. Consider the reaction:

$$2NO(g) + Br_2(g) \rightarrow 2NOBr(g)$$
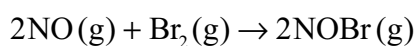
One suggested mechanism is:

$$NO(g) + Br_2(g) \xrightleftharpoons{k_1} NOBr_2(g) \qquad \textit{fast}$$

$$NOBr_2(g) + NO(g) \xrightarrow{k_2} 2NOBr(g) \qquad \textit{slow}$$
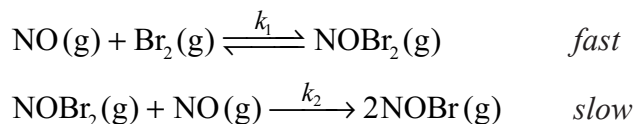
Which statements are correct?

    I. $NOBr_2(g)$ is an intermediate.

    II.   The second step is the rate-determining step.

    III.   rate $= k[NO]^2[Br_2]$

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

21. What happens to the position of equilibrium and the value of K_c when the temperature is increased in the following reaction?

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g) \qquad \Delta H^\ominus = +87.9 \text{ kJ mol}^{-1}$$

	Position of equilibrium	**Value of K_c**
A.	shifts towards reactants	decreases
B.	shifts towards reactants	increases
C.	shifts towards products	decreases
D.	shifts towards products	increases

Turn over

22. Which statement is correct about the relationship between the vapour pressure, P, of ethanol and temperature, T?

    A. P increases linearly with increasing T.

    B. P decreases linearly with increasing T.

    C. P increases exponentially with increasing T.

    D. P decreases exponentially with increasing T.

23. Which reaction represents an acid–base reaction according to the Lewis theory but not according to the Brønsted–Lowry theory?

    A. $CO_3^{2-}(aq) + H_3O^+(aq) \rightleftharpoons H_2O(l) + HCO_3^-(aq)$

    B. $CH_3COOH(aq) + NH_3(aq) \rightleftharpoons NH_4^+(aq) + CH_3COO^-(aq)$

    C. $NH_3(aq) + HF(aq) \rightleftharpoons NH_4^+(aq) + F^-(aq)$

    D. $CuSO_4(s) + 5H_2O(l) \rightleftharpoons CuSO_4 \cdot 5H_2O(s)$

24. Four aqueous solutions are listed below.

    W. $0.100 \ mol \, dm^{-3} \ HNO_3(aq)$

    X. $0.001 \ mol \, dm^{-3} \ HNO_3(aq)$

    Y. $0.100 \ mol \, dm^{-3} \ KOH(aq)$

    Z. $0.001 \ mol \, dm^{-3} \ KOH(aq)$

What is the correct order of **increasing** pH of these solutions?

    A. $W < X < Y < Z$

    B. $W < X < Z < Y$

    C. $X < W < Y < Z$

    D. $X < W < Z < Y$

25. Penicillin G (benzyl penicillin) contains a number of different functional groups and has the following structure:
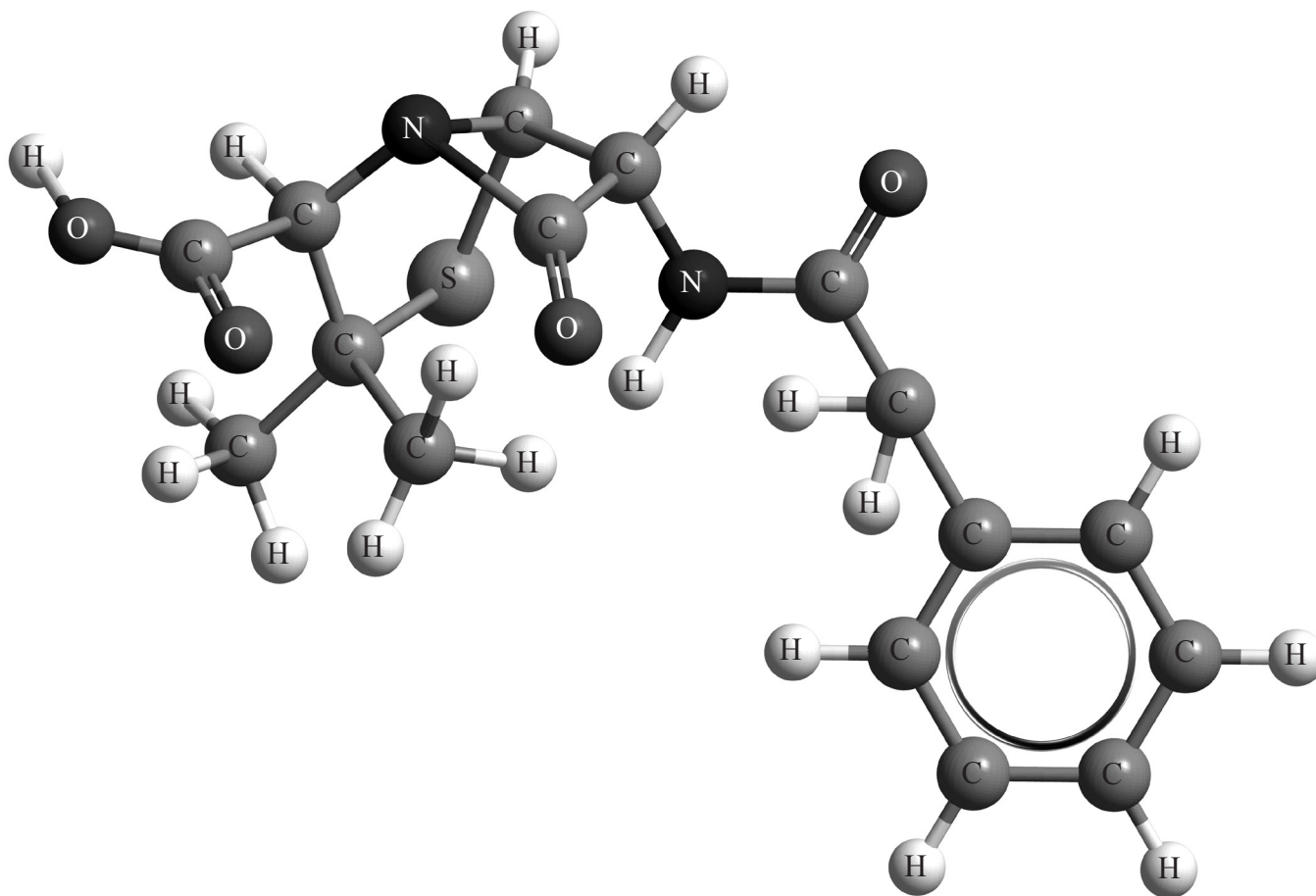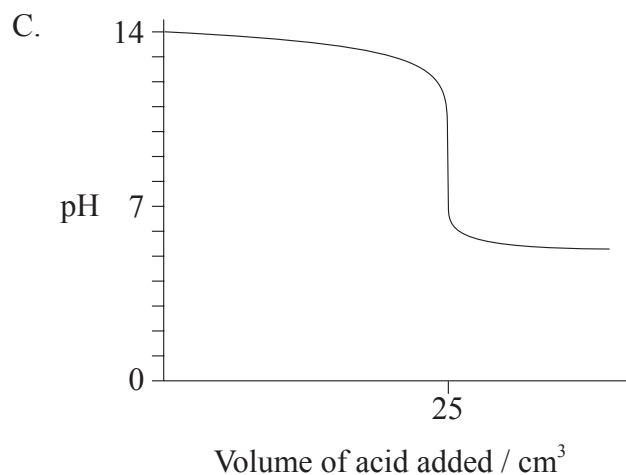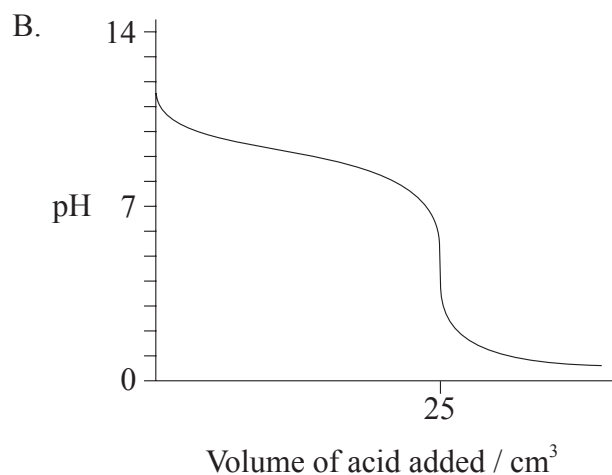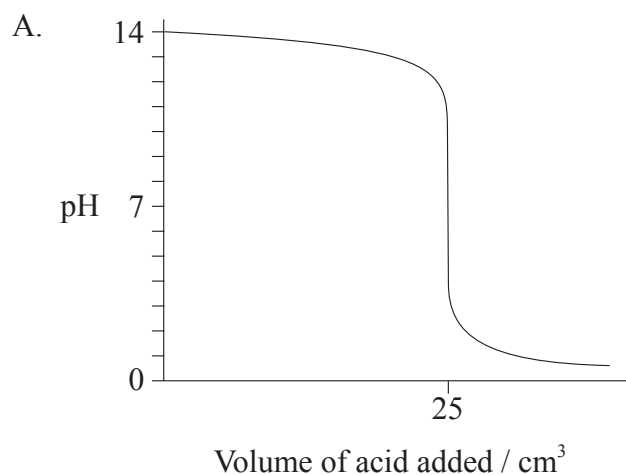

It is a weak monoprotic acid ($pK_a = 2.79$ at 298 K). At 298 K, the ionic product constant for water, $K_w = 1.00 \times 10^{-14}$. What is the value of pK_b for the conjugate base of penicillin G and which functional groups are present in penicillin G?

	pK_b	Selected functional groups in penicillin G
A.	11.21	carboxylic acid, amine
B.	2.79	carboxylic acid, amide
C.	11.21	ketone, alcohol
D.	11.21	carboxylic acid, benzene ring

26. Which mixtures are buffer solutions?

      I. $KHSO_4$ (aq) and H_2SO_4 (aq)

      II. CH_3COONa (aq) and CH_3COOH (aq)

      III. $HCOOK$ (aq) and $HCOOH$ (aq)

A.   I and II only

B.   I and III only

C.   II and III only

D.   I, II and III

27. Which titration curve is produced by the titration of 25 cm³ of 1.00 mol dm⁻³ NaOH with 1.00 mol dm⁻³ CH_3COOH?
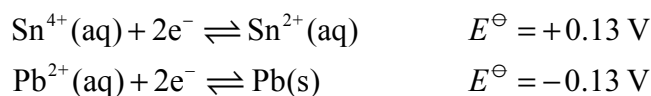
28. Consider the following reaction:

$$3Sn^{2+}(aq) + Cr_2O_7{}^{2-}(aq) + 2H^+(aq) \rightarrow 2Cr^{3+}(aq) + 3SnO_2(s) + H_2O(l)$$
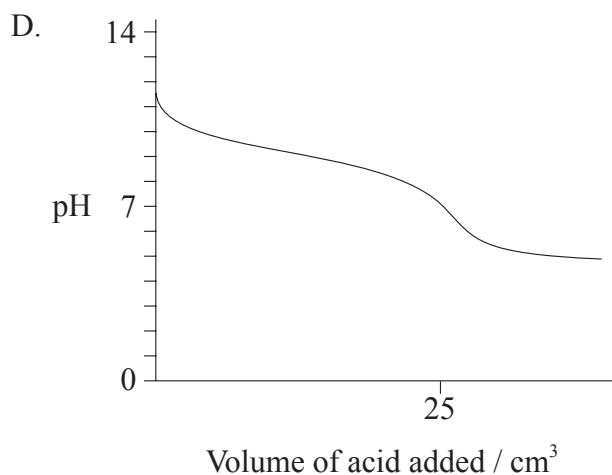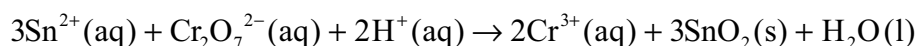
Which statement is correct?

A. Sn^{2+} is the oxidizing agent because it undergoes oxidation.

B. Sn^{2+} is the reducing agent because it undergoes oxidation.

C. $Cr_2O_7{}^{2-}$ is the oxidizing agent because it undergoes oxidation.

D. $Cr_2O_7{}^{2-}$ is the reducing agent because it undergoes oxidation.

29. What occurs during the operation of a voltaic cell based on the following overall reaction?

$$2Ag^+(aq) + Cu(s) \rightarrow 2Ag(s) + Cu^{2+}(aq)$$
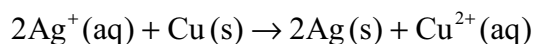
	External circuit	**Ion movement in solution**
A.	electrons move from $Cu(s)$ to $Ag(s)$	$Ag^+(aq)$ move towards $Cu(s)$
B.	electrons move from $Ag(s)$ to $Cu(s)$	$Ag^+(aq)$ move towards $Ag(s)$
C.	electrons move from $Cu(s)$ to $Ag(s)$	$Ag^+(aq)$ move towards $Ag(s)$
D.	electrons move from $Ag(s)$ to $Cu(s)$	$Cu^{2+}(aq)$ move towards $Cu(s)$

30. Consider the following standard electrode potentials:

$$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq) \qquad E^\ominus = +0.13 \text{ V}$$
$$Pb^{2+}(aq) + 2e^- \rightleftharpoons Pb(s) \qquad E^\ominus = -0.13 \text{ V}$$

What is the value of the cell potential, in V, for the spontaneous reaction that occurs when the two half-cells are connected together?
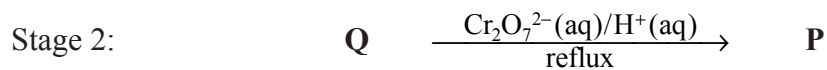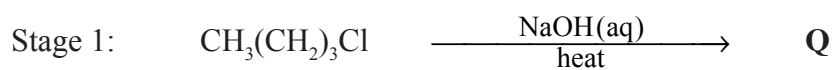
A.   −0.26

B.   0.00

C.   +0.13

D.   +0.26

31. Two electrolytic cells are connected **in series** and the same current passes through each cell. The first cell contains silver electrodes in silver nitrate solution. The second cell contains copper electrodes in copper(II) sulfate solution. In one experiment 1.00 g of silver is deposited in the first cell. What mass of copper, in g, is deposited in the second cell?

A. $\dfrac{1.00}{107.87}$

B. $\dfrac{1.00}{63.55}$

C. $\dfrac{1.00}{107.87} \times \dfrac{63.55}{2}$

D. $\dfrac{1.00}{107.87} \times 63.55$

32. What is the name of $(CH_3)_2CHCOCH_3$ applying IUPAC rules?

A. 3,3-dimethylpropan-2-one

B. 3-methylbutan-2-one

C. 2-methylbutan-3-one

D. 3-methylbutanal

33. The drug methadone contains several different functional groups. Which functional groups are present in methadone?
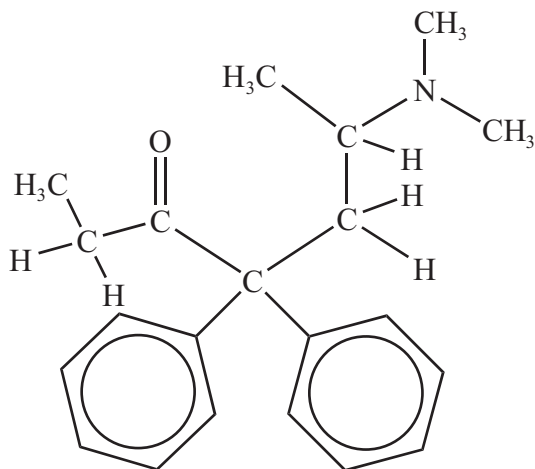

A.   ketone, benzene ring, amine

B.   ketone, benzene ring, amide

C.   aldehyde, alkene, amide

D.   aldehyde, alkene, amine

34. Which compound has the **lowest** boiling point?

A. $CH_3CH_2CH_2OH$

B. $CH_3CH_2CH_2Br$

C. CH_3CH_2COOH

D. $CH_3CH_2CH_2CH_3$

Turn over

35. Which organic compounds, **Q** and **P**, are formed in the following two-stage reaction pathway?

Stage 1: $CH_3(CH_2)_3Cl$ $\xrightarrow[\text{heat}]{\text{NaOH(aq)}}$ **Q**

Stage 2:   **Q** $\xrightarrow[\text{reflux}]{Cr_2O_7^{2-}(aq)/H^+(aq)}$ **P**

	Q	P
A.	$CH_3(CH_2)_3OH$	$CH_3(CH_2)_3COOH$
B.	$CH_3(CH_2)_3OH$	$CH_3(CH_2)_2COOH$
C.	$CH_3CH_2CH=CH_2$	no reaction product formed
D.	$CH_3(CH_2)_3OH$	$CH_3(CH_2)_2CHO$

36. What is the organic product, **Y**, formed in the following reaction?

$$CH_3(CH_2)_3CN + 2H_2 \xrightarrow{\text{Ni}} Y$$
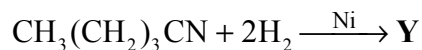
A. $CH_3(CH_2)_3NH_2$

B. $CH_3(CH_2)_4NH_2$

C. $CH_3(CH_2)_3CH_3$

D. $CH_3(CH_2)_3COOH$

37. What organic product is formed from the reaction of benzoic acid, C_6H_5COOH, with ethylamine, $CH_3CH_2NH_2$?

A. $C_6H_5CONHCH_2CH_3$

B. $C_6H_5CONH_2$

C. $CH_3CH_2CONHC_6H_5$

D. $C_6H_5COOCH_2CH_3$

38. Which compound has a chiral carbon?

    A.   Propan-2-ol

    B.   1-bromo-2-methylbutane

    C.   3-bromopentane

    D.   Ethane-1,2-diol

39. What effect of optical isomers on plane-polarized light can be measured using a polarimeter?

    A.   Reflection

    B.   Emission

    C.   Rotation

    D.   Absorption

40. The relationship between the pressure, P, and the volume, V, of a fixed amount of gas at a constant temperature is investigated experimentally. Which statements are correct?

    I.   A graph of V against P will be a curve (non-linear).

    II.   A graph of V against $\dfrac{1}{P}$ will be linear.

    III. $V = \text{constant} \times \dfrac{1}{P}$

    A.   I and II only

    B.   I and III only

    C.   II and III only

    D.   I, II and III