Diploma Programme
Programme du diplôme
Programa del Diploma

Chemistry
Higher level
Paper 1

Thursday 12 May 2016 (morning)

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]**.

2216 – 6101

16 pages

The Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** 1.01			Atomic number **Element** Relative atomic mass														2 **He** 4.00
2	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
3	11 **Na** 22.99	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
4	19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.63	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.90
5	37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.96	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
6	55 **Cs** 132.91	56 **Ba** 137.33	57† **La** 138.91	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
7	87 **Fr** (223)	88 **Ra** (226)	89‡ **Ac** (227)	104 **Rf** (267)	105 **Db** (268)	106 **Sg** (269)	107 **Bh** (270)	108 **Hs** (269)	109 **Mt** (278)	110 **Ds** (281)	111 **Rg** (281)	112 **Cn** (285)	113 **Unt** (286)	114 **Uug** (289)	115 **Uup** (288)	116 **Uuh** (293)	117 **Uus** (294)	118 **Uuo** (294)

†	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.05	71 **Lu** 174.97
‡	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. Which equation represents sublimation?

A. $2Al(s) + 3I_2(g) \rightarrow 2AlI_3(s)$

B. $HgCl_2(s) \rightarrow HgCl_2(g)$

C. $I_2(g) \rightarrow I_2(s)$

D. $CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

2. In which mixture is NaOH the limiting reagent?

A. $0.20\,mol\ NaOH + 0.10\,mol\ H_2SO_4$

B. $0.10\,mol\ NaOH + 0.10\,mol\ H_2SO_4$

C. $0.20\,mol\ NaOH + 0.10\,mol\ HNO_3$

D. $0.10\,mol\ NaOH + 0.10\,mol\ HNO_3$

3. Why do gases deviate from the ideal gas law at high pressures?

A. Molecules have finite volume.

B. Cohesive forces increase the volume from the ideal.

C. Increasing pressure increases the temperature of the gas.

D. Collisions between molecules occur more frequently as pressure increases.

4. Which is correct for the chromium isotope $^{53}_{24}Cr$?

A. 24 neutrons and 53 nucleons

B. 24 protons and 29 nucleons

C. 24 protons and 29 neutrons

D. 24 electrons and 53 neutrons

5. Which electron configuration is correct for the selenide ion, Se^{2-}?

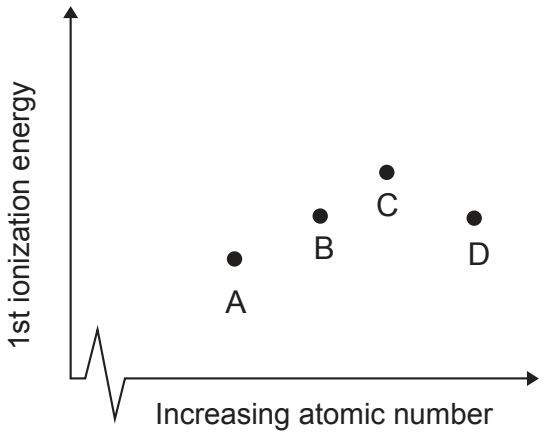
A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 4d^{10}\ 4p^4$

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

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

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

6. The diagram shows the first ionization energies of four consecutive elements in the periodic table. Which element is in Group 14?



7. Which element is a metalloid?

A. Co

B. As

C. Cs

D. Es

8. Which periodic trend is described correctly?

	Trend in	Down the group (top to bottom)	Across the period (left to right)
A.	atomic radius	increases	increases
B.	ionic radius	decreases	increases
C.	first ionization energy	decreases	decreases
D.	electronegativity	decreases	increases

9. Which does **not** affect the colour of the complex ion formed by a particular transition metal?

A. Oxidation state of the metal

B. Number of ligands in the complex

C. Identity of ligands in the complex

D. Isotope of the metal

10. Which best explains why transition metal complexes are coloured?

A. As electrons return to lower energy levels, light of a certain colour is emitted, and the complementary colour is observed.

B. As electrons return to lower energy levels, light of a certain colour is emitted, so the complex appears to have the same colour.

C. As electrons are promoted to higher energy levels, light of a certain colour is absorbed, and the complementary colour is observed.

D. As electrons are promoted to higher energy levels, light of a certain colour is absorbed, so the complex appears to have the same colour.

11. Which species breaks the octet rule?

A. PCl_3

B. BF_4^-

C. SCl_4

D. NH_4^+

12. Which compound contains both ionic and covalent bonds?

A. SiH_4

B. $NaNO_3$

C. H_2CO

D. Na_2S

13. Which of the following are van der Waals' forces?

I. Dipole-dipole forces
II. Hydrogen bonds
III. London (dispersion) forces

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

14. In which group do both compounds contain delocalized electrons?

A. C_6H_{10}, C_5H_{10}

B. Na_2CO_3, NaOH

C. $NaHCO_3$, C_6H_6

D. $NaHCO_3$, C_6H_{12}

15. Which of the following is correct?

	Atom	Number of electron domains	Molecular geometry	Hybridization
A.	C in C_2H_2	2	linear	sp
B.	C in C_2H_6	4	square planar	sp^3
C.	N in NH_3	3	trigonal pyramidal	sp^3
D.	O in H_2O	4	bent	sp^2

16. The equation for the formation of ethyne is:

$$2C(s) + H_2(g) \rightarrow C_2H_2(g)$$

What is the enthalpy change, in kJ, for this reaction using the enthalpy of combustion data below?

Reaction	$\Delta H^\ominus$ / kJ
$C(s) + O_2(g) \rightarrow CO_2(g)$	–394
$2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$	–572
$2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(l)$	–2602

A. $2 \times (-394) + \frac{1}{2}(-572) - \frac{1}{2}(-2602)$

B. $2 \times (-394) + (-572) - (-2602)$

C. $2 \times (-394) + \frac{1}{2}(-572) + \frac{1}{2}(-2602)$

D. $2 \times (-394) + (-572) + (-2602)$

17. Which equation represents the average bond enthalpy of the Si–H bond in SiH_4?

A. $SiH_4(g) \rightarrow SiH_3(g) + H(g)$

B. $\frac{1}{4}SiH_4(g) \rightarrow \frac{1}{4}Si(g) + H(g)$

C. $SiH_4(g) \rightarrow SiH_3(g) + \frac{1}{2}H_2(g)$

D. $SiH_4(g) \rightarrow Si(g) + 4H(g)$

18. Which transition represents an enthalpy of hydration?

A. $2H_2O(l) \rightarrow H_3O^+(aq) + OH^-(aq)$

B. $NaCl(s) \rightarrow Na^+(aq) + Cl^-(aq)$

C. $K^+(s) \rightarrow K^+(aq)$

D. $K^+(g) \rightarrow K^+(aq)$

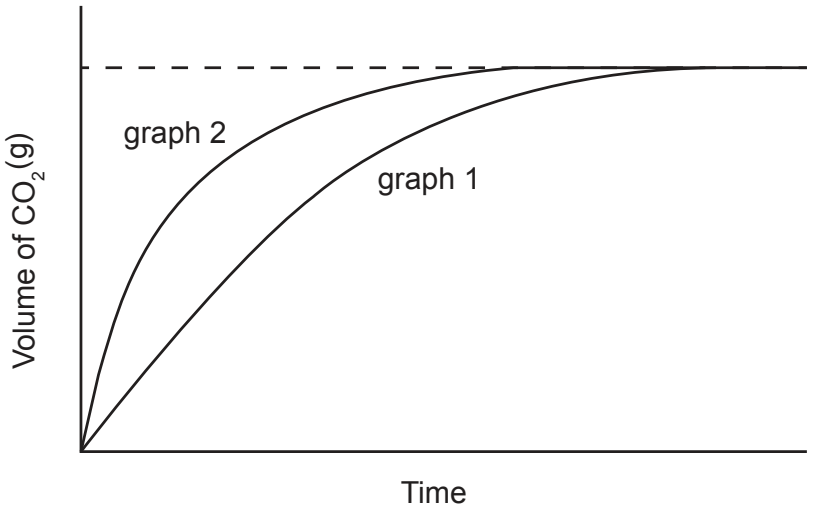
19. What are the signs for the entropy changes associated with this reaction?

$$H_2O(g) \rightarrow H_2O(l)$$

	$\Delta S_{surroundings}$	ΔS_{system}
A.	+	−
B.	+	+
C.	−	−
D.	−	+

20. Graph 1 shows a plot of volume of $CO_2(g)$ against time for the reaction of $CaCO_3(s)$ with $1.00\,mol\,dm^{-3}$ $HCl(aq)$. The acid is the limiting reagent and entirely covers the lumps of $CaCO_3(s)$.

Which set of conditions is most likely to give the data plotted in graph 2 when the same mass of $CaCO_3(s)$ is reacted with the same volume of $HCl(aq)$ at the same temperature?



	Size of lumps	Concentration of acid / $mol\,dm^{-3}$
A.	larger	1.00
B.	smaller	0.05
C.	smaller	1.00
D.	larger	0.05

21. The data shows the effect of changing reactant concentrations on the rate of the following reaction at 25 °C.

$$F_2(g) + 2ClO_2(g) \rightarrow 2FClO_2(g)$$

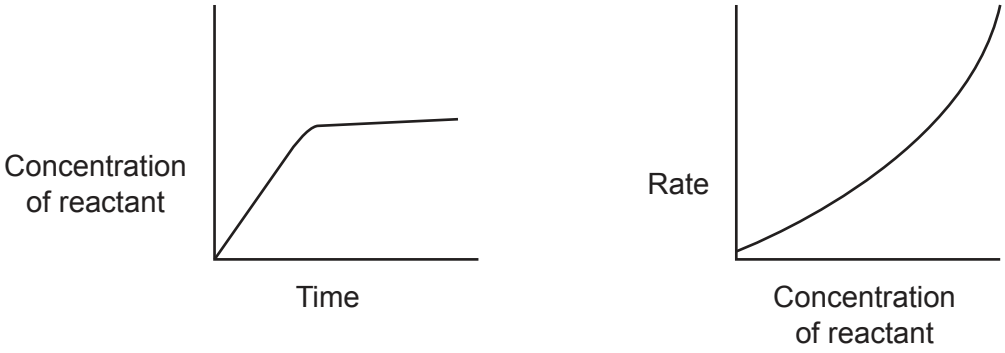
Initial $[F_2(g)]$ / mol dm^{-3}	**Initial $[ClO_2(g)]$ / mol dm^{-3}**	**Initial rate of reaction / mol dm^{-3} s^{-1}**
0.100	0.010	1.20×10^{-3}
0.100	0.030	3.60×10^{-3}
0.150	0.010	1.80×10^{-3}

Which is correct for the order of reaction with respect to the fluorine concentration and the overall order of reaction?

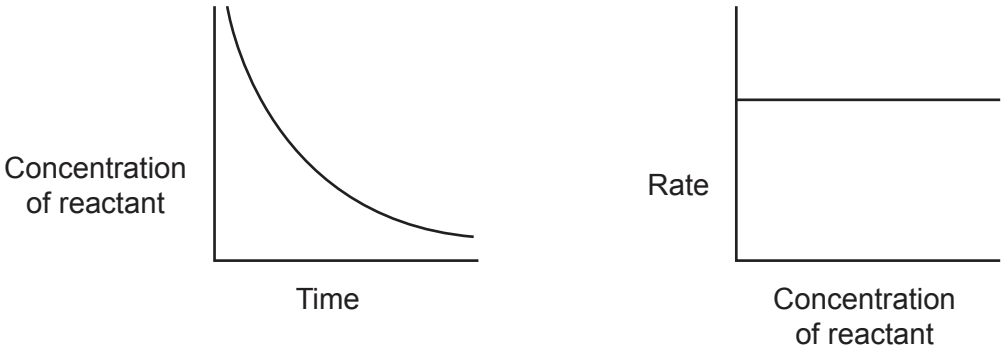
	Order with respect to $[F_2(g)]$	**Overall order**
A.	2	1
B.	2	2
C.	1	1
D.	1	2

22. Which pair of graphs represents the same order of reaction?

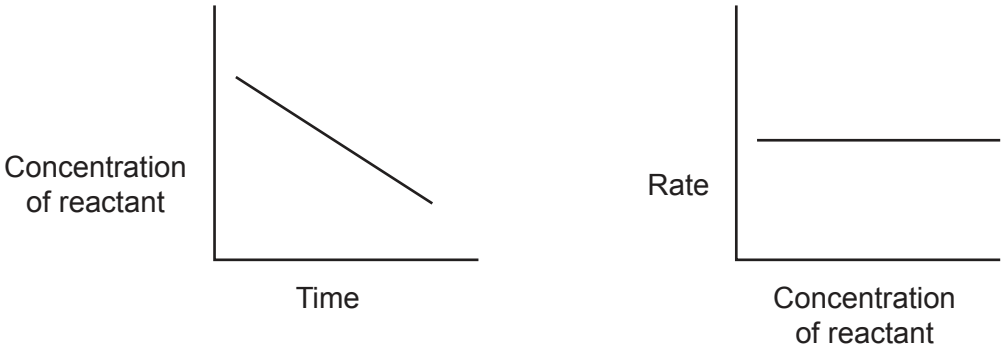
A.



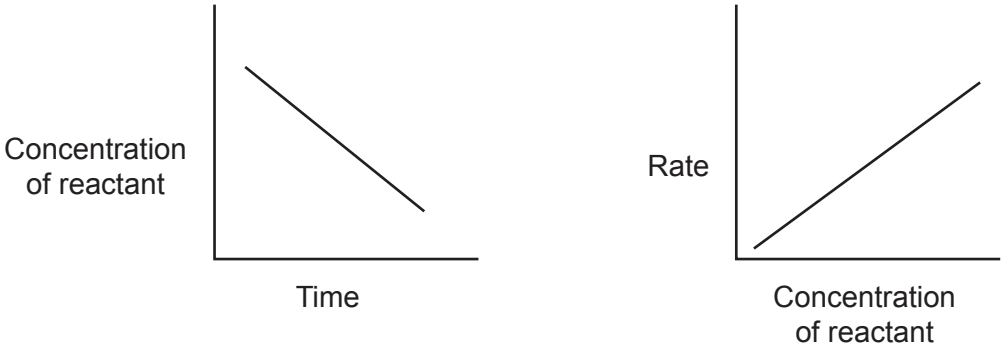
B.



C.



D.



23. Which of the terms in the Arrhenius equation takes into account the orientation of the molecules?

$$k = Ae^{\frac{-E_a}{RT}}$$

A. A

B. E_a

C. R

D. T

24. What is the effect of increasing temperature on the equilibrium?

$$ClNO_2(g) + NO(g) \rightleftharpoons ClNO(g) + NO_2(g) \qquad \Delta H^{\ominus} = -18.4\,kJ$$

	Position of equilibrium	K_c
A.	moves to left	decreases
B.	moves to left	no change
C.	moves to right	no change
D.	moves to right	increases

25. Which is correct for an isolated system in equilibrium?

	Gibbs free energy	**Entropy**
A.	maximum	maximum
B.	maximum	minimum
C.	minimum	maximum
D.	minimum	minimum

26. Which is a conjugate Brønsted–Lowry acid-base pair?

$$CH_3COOH\,(aq) + H_2O\,(l) \rightleftharpoons CH_3COO^-\,(aq) + H_3O^+\,(aq)$$

A. CH_3COO^- / H_3O^+

B. H_2O / CH_3COO^-

C. H_2O / H_3O^+

D. CH_3COOH / H_2O

27. Aqueous solutions of a weak acid and a strong acid of equal concentration are compared. Which statements are correct?

I. The weak acid is less dissociated than the strong acid.
II. The strong acid reacts with a metal oxide but the weak acid does not.
III. The strong acid has greater conductivity than the weak acid.

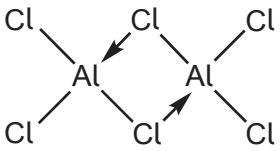
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

28. The diagram represents the bonding in aluminium chloride.



Which statement is correct?

A. The aluminium atoms behave as Lewis acids.

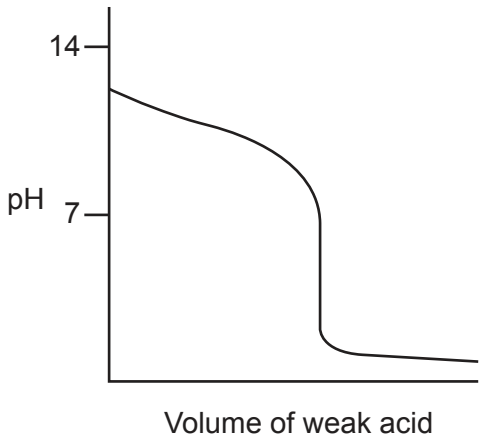
B. The aluminium atoms behave as Lewis bases.

C. One aluminium atom is a Lewis base and the other a Lewis acid.

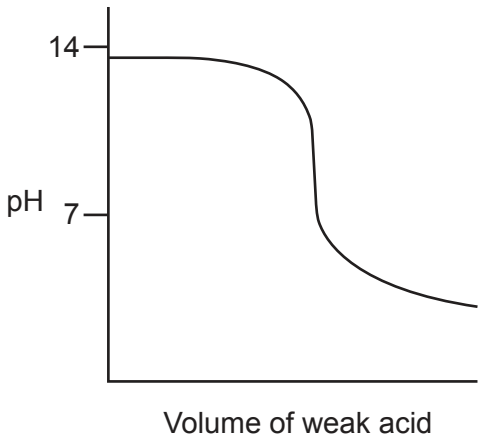
D. One chlorine atom is a Lewis base and the other a Lewis acid.

29. Which titration curve would occur when a weak acid is added to a strong base?

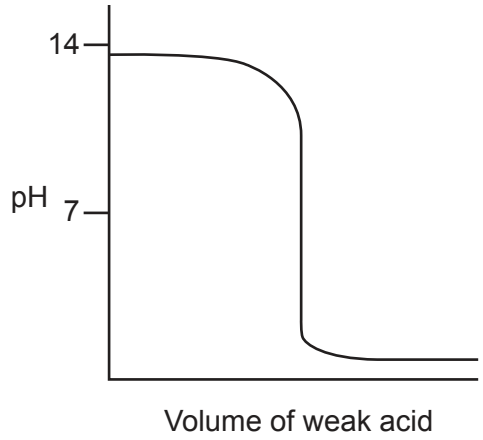
A.



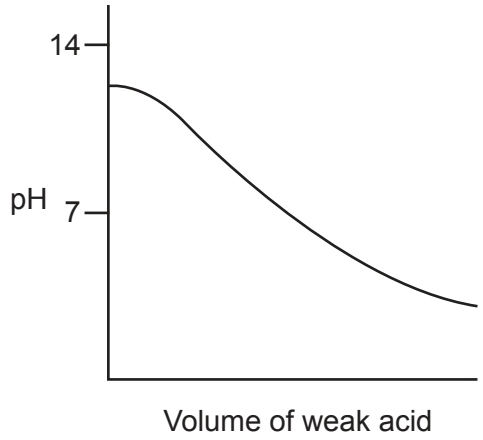
B.



C.



D.



30. Applying IUPAC rules, what is the name of MnO_2?

A. Magnesium(II) oxide

B. Manganese(II) oxide

C. Magnesium(IV) oxide

D. Manganese(IV) oxide

31. Which statement is correct for a voltaic but **not** for an electrolytic cell?

A. An electrolyte is required.

B. The anode is where oxidation occurs.

C. Ions move in the electrolyte.

D. Electrons flow from the negative electrode to the positive electrode.

32. Which compound forms both hydrogen and oxygen at the electrodes when a concentrated aqueous solution is electrolyzed?

A. KI

B. NaCl

C. H_2SO_4

D. $AgNO_3$

33. *z* mol of copper is deposited from $CuSO_4(aq)$ by a current, *I*, in time *t*. What is the amount of silver, in mol, deposited by electrolysis from $AgNO_3(aq)$ by a current, $\frac{I}{2}$, in time 2*t*?

A. $\frac{z}{4}$

B. $\frac{z}{2}$

C. z

D. $2z$

34. What is the general formula of the alkyne series?

A. C_nH_n

B. C_nH_{2n-2}

C. C_nH_{2n}

D. C_nH_{2n+2}

35. Which statement is correct about the major reaction between 1-chloropropane, $CH_3CH_2CH_2Cl$, and dilute sodium hydroxide solution, $NaOH(aq)$?

A. The rate equation is second order.

B. The hydroxide ion acts as a Brønsted–Lowry base.

C. The reaction has two distinct steps.

D. Water is a product.

36. Which molecule can be both reduced by sodium borohydride, $NaBH_4$, and oxidized by warm acidified potassium dichromate(VI)?

A. $CH_3CHOHCH_2CH_3$

B. $(CH_3)_3CCHO$

C. $(CH_3)_3COH$

D. $(CH_3)_3CCOC(CH_3)_3$

37. Which molecule contains a chiral carbon?

A. $CH_3CHOHCH_2CH_3$

B. $(CH_3)_3CCHO$

C. $(CH_3)_3COH$

D. $(CH_3)_3COC(CH_3)_3$

38. A measuring cylinder was used to obtain a known volume of a liquid. The volume was read from the top of the meniscus and the liquid completely emptied into a flask. The exact same process was then repeated. Which statement is correct about the overall described procedure and the volumes measured?

A. There is a systematic error and the volumes measured are accurate.

B. There is a random error and the volumes measured are accurate.

C. There is a random error and the volumes measured are inaccurate.

D. There is a systematic error and the volumes measured are inaccurate.

39. Which molecule has an index of hydrogen deficiency (IHD) = 1?

A. C_6H_6

B. C_2Cl_2

C. C_4H_9N

D. C_2H_6O

40. Which analytical technique is used to measure bond lengths in solid compounds?

A. IR spectroscopy

B. Mass spectroscopy

C. NMR spectroscopy

D. X-ray crystallography