H2 Chemistry 9729 **AJC 2017 JC1 PROMO** **Paper 1 – 30 marks**

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

A	**4**
B	**8**
C	**9**
D	**9**

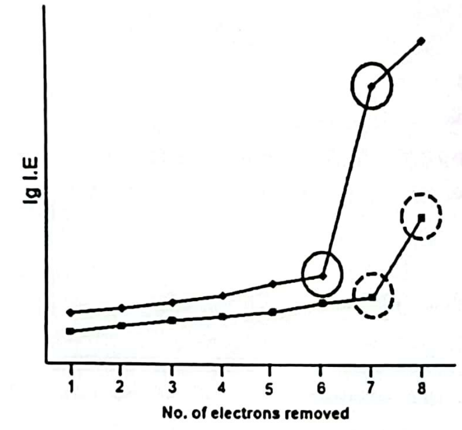
Anderson Junior College
H2 Chemistry 9729 **2017 JC1 PROMO Paper 1 Worked Solutions**

1 **D**

	no. of protons	no. of neutrons	no. of electrons	electronic configuration
^{68}Ga	31	37	31	[Ar] $3d^{10}$ $\mathbf{4s^2\ 4p^1}$
^{68}Ge	32	36	32	[Ar] $3d^{10}$ $\mathbf{4s^2\ 4p^2}$

*no. of nucleons = no. of protons + no. of neutrons

2 **B**



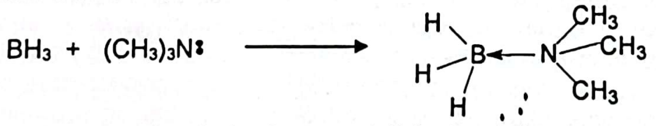
sharp increase between 6th and 7th I.E
⇒ presence of 6 valence electrons
⇒ element is in Group 16

sharp increase between 7th and 8th I.E
⇒ presence of 7 valence electrons
⇒ element is in Group 17

Since the Group 16 element has higher successive I.Es compared to the Group 17 element
⇒ the Group 16 element is in Period 2 (i.e. O)
⇒ the Group 17 element is in Period 3 (i.e. Cl)

3 The ground state of a Group 16 element has 6 valence electrons and hence has a valence shell configuration of $\mathbf{ns^2\ np^4}$, NOT $ns^2\ np^6$! **D**

4 The addition reaction between $(CH_3)_3N$ and BH_3 forms the product, $(CH_3)_3N{\rightarrow}BH_3$. The structure is shown below: **D**



B atom in BH_3 molecule is electron–deficient as it has only 6 electrons around it. Hence, the B atom can accept another 2 electrons from the lone pair of N atom. By forming a <u>dative bond</u> with the N atom of $(CH_3)_3N$, the B atom achieves the octet configuration. Statement 1 is correct.

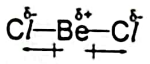
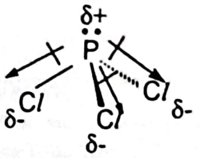
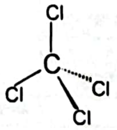
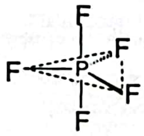
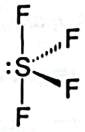
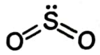
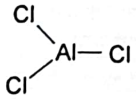
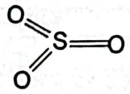
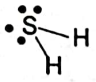
The molecular shape around B changes from **trigonal planar** (not trigonal pyramidal) in BH_3 (3 bond pairs, 0 lone pair around the central B atom) **to tetrahedral** in the product (4 bond pairs, 0 lone pair around the central B atom). Statement 2 is not correct.

Hydrogen bonds are not present in the product, as shown in the structure above (the H atoms are not available for hydrogen bonding as they are not covalently bonded to F or O or N atom). Statement 3 is incorrect.

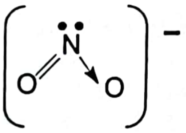
5 The 3p valence orbital of silicon is larger than the 2p valence orbital of carbon. **B**

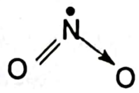
The larger valence orbital of silicon is <u>more diffused</u> and when these orbitals overlap in forming the Si–Si bond, the accumulation of electron density within the inter–nuclei region is lower. Thus the overlap of Si orbitals is <u>less effective</u>, resulting in weaker bond strength. Hence the bond energy of Si–Si bond is lower than that of the C–C bond.

6 B

	non–polar molecule (no bond dipoles or bond dipoles cancel out)	polar molecule (bond dipoles do not cancel out)
A	O=O 	
B	All the molecules in Option B are non–polar.   	
C	S=C=S	 
D	 	

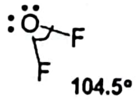
7 A Both NO_2^- and NO_2 have bent shapes. C

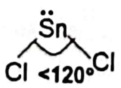




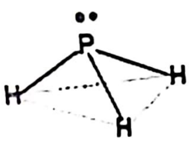
The electrostatic repulsion exerted on the bond pairs by the lone pair of electrons on N atom of NO_2^- is greater than that by the single electron on the N atom of NO_2. Thus the bond angle of NO_2^- is smaller than that in NO_2.

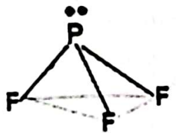
B





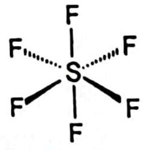
C



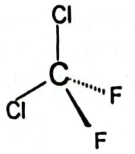


F is more electronegative than H. Hence, the bonding electrons in P–F bond are closer to the F atoms. There is less crowding of electron density around the P atom in PF_3 leading to less inter–electronic repulsion between the electron pairs around the P atom. Therefore, the bond angle in PF_3 is smaller and that in PH_3 is larger.

D



Bond angle: 90°

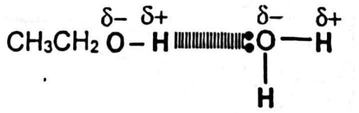


Bond angle: approx. 109°

8 **1** Each water molecule in ice is bonded to 4 neighbouring water molecules through **B**
hydrogen bonding in a tetrahedral manner, while each water molecule in (liquid) water is bonded to 2 water molecules, on the average. The open structure formed by hydrogen bonding in ice (refer to diagram in lecture notes) i.e. lots of empty space between molecules explains why the density of ice is lower than that of water. When ice melts, some of the hydrogen bonds are weakened and the volume contracts due to closer packing of the molecules.

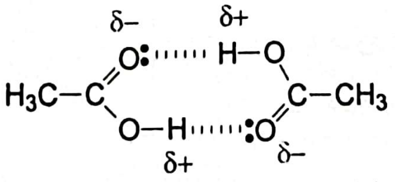
2 Pentan–1–ol, $CH_3CH_2CH_2CH_2CH_2OH$, has a higher boiling point than butan–1–ol, $CH_3CH_2CH_2CH_2OH$, as the longer non–polar hydrocarbon chain ($CH_3CH_2CH_2CH_2CH_2$–) in pentan–1–ol results in stronger instantaneous dipole–induced dipole attractions than that due to the shorter hydrocarbon chain in butan–1–ol. Intermolecular hydrogen bonding in both compounds have similar strength as both have only 1 hydrogen (on the –OH group) available for hydrogen bonding.

3 Hydrogen bonding between ethanol and water enables ethanol molecules to dissolve in water.



$$CH_3CH_2\overset{\delta-}{O}-\overset{\delta+}{H}\cdots\cdots:\overset{\delta-}{\underset{\displaystyle H}{\underset{|}{O}}}-\overset{\delta+}{H}$$

In non–polar solvents, CH_3COOH dimerises through hydrogen bonding.



(When dissolved in water, ethanoic acid molecules will form hydrogen bonds with the water molecules because water is in large excess. Hence, no dimerisation occurs when it is dissolved in water.)

9 Using $pV = nRT$ **D**

A	when n and T are constant, $V \alpha 1/p$	graph of **V against *p*** is a reciprocal curve
B	when n and T are constant, $V \alpha 1/p$	graph of **V against 1/*p*** is a straight line through the origin
C	when n and T are constant, pV = constant	graph of ***p*V against V** is a horizontal straight line
D	when n and T are constant, pV = constant	graph of ***p*V against *p*** is a horizontal straight line

10 Using $pV = nRT$ **D**

When n and T are constant, pV = constant

i.e. $p_1V_1 = p_2V_2$

$p_2 = p_1V_1 / V_2$

p_{He} = (5 kPa)(3 dm^3) / 1.5 dm^3 = 10 kPa

p_{Ar} = (3 kPa)(2 dm^3) / 1.5 dm^3 = 4 kPa

Total pressure = $p_T = p_{He} + p_{Ar}$ = 10 + 4 = **14 kPa**

11 **B**

Period 3 element	**structure**	**melting point**
Na, Mg, Al	giant ionic	high
Si	giant molecular	very high
S, Cl, Ar	simple molecular	low

12 Phosphorus (P) has simple molecular structure. (eliminate option 2) **A**

Litmus indicator solution turns red in acidic solutions and blue in alkaline solutions – and it turns purple in neutral solutions.

	effect on litmus solution	**reason**
Al_2O_3	turns purple	Al_2O_3 is insoluble in water; resulting solution is neutral
$AlCl_3$	turns red	$AlCl_3$ undergoes slight hydrolysis in water to produce a weakly acidic solution

	effect on litmus solution	**reason**
SiO_2	turns purple	SiO_2 is insoluble in water; resulting solution is neutral
$SiCl_4$	turns red	$SiCl_4$ undergoes complete hydrolysis in water to produce a strongly acidic solution

	effect on litmus solution	**reason**
Na_2O	turns blue	Na_2O dissolves completely in water to produce a strongly alkaline solution (NaOH)
NaCl	turns purple	NaCl does not hydrolyse in water; resulting solution is neutral

13 Down Group 2, **C**

- E° becomes more negative
- reducing power (i.e. ease of **oxidation**) of the element increases

Group 2 Element	E° / V
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2.38
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	−2.87
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	−2.89
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	−2.90

Down Group 2,

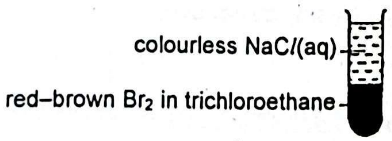
- cation becomes larger (greater ionic radius)
- weaker ion–dipole interactions formed between cation and water molecules
- less heat evolved hence magnitude of enthalpy change of hydration of cation decreases

14 Down Group 2, **C**

- charge density of cation decreases due to increasing ionic radius
- hence polarising effect on anion decreases
- electron cloud of anion less distorted; C–O bond in carbonate weakened to lesser extent
- thermal stability of the carbonate increases
- hence decomposition temperature of the carbonate increases

15 Each halide ion can be oxidised by the halogen above it in Group 17. **D**
A more reactive (i.e. more strongly oxidising) halogen displaces a less reactive one from its compound.

$2NaBr + Cl_2 \longrightarrow Br_2 + 2NaCl$



16 **A** *Relative molecular mass* has no unit since it is a ratio of 2 masses that in the same "unit". The unit "g mol^{-1}" is the unit for molar mass. **D**

B *Relative molecular mass* is the ratio of the average mass of a molecule to $\frac{1}{12}$ the mass of one ^{12}C atom.

C The statement has only considered the mass of only 1 type of isotope of an element. It is incorrect to use only the mass of only 1 type of isotope of an element to define *the relative atomic mass* of an element as it is a weighted average of the masses of all isotopes for the element.

D There can be more than 1 type of isotope in 1 mole of atoms. Hence by considering the mass of 1 mole of atoms, weighted average of the masses of all isotopes would have been taken into account. Hence relative atomic mass is obtained when the mass of 1 mole atoms is divided by $\frac{1}{12}$ the mass of 1 mole of ^{12}C.

17 **D**

A	no change in oxidation states of elements
B	
C	
D	oxidation state of Ti changes from +3 to +4 (oxidation) oxidation state of O changes from 0 to –2 (reduction)

18 Verify the relative atomic mass of the element for each option using the following expression: **B**

$$A_r = \frac{\sum(\text{relative abundance of isotope} \times \text{relative isotopic mass})}{100}$$

Option B: $A_r = \frac{(94.9 \times 32) + (0.8 \times 33) + (4.3 \times 34)}{100} = 32.094$

19 $HOC_6H_4CO_2H + (CH_3CO)_2O \longrightarrow CH_3CO_2C_6H_4CO_2H + CH_3CO_2H$ **C**

Given that the typical yield is 75% to obtain a mass of 5 g aspirin,

max mass of aspirin = $\frac{100}{75} \times 5\text{ g} = 6.6667\text{ g}$

maximum no. of moles of aspirin = $\frac{6.6667}{180} = 0.03704$ mol

∴ no. of moles of $(CH_3CO)_2O$ = 0.03704 mol

mass of $(CH_3CO)_2O$ required = 0.03704 × 102.0 = **<u>3.78 g</u>**

20 Method 1 **A**

	ΔH / kJ mol^{-1}	Represents
$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$	–286	$\Delta H_f(H_2O)$
$C(s) + O_2(g) \longrightarrow CO_2(g)$	–394	$\Delta H_f(CO_2)$

Given that $C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$ $\Delta H_r = -1211$

$\Delta H_r = \Delta H_f(\text{products}) - \Delta H_f(\text{reactant})$
$-1211 = 3\Delta H_f(H_2O) + 2\Delta H_f(CO_2) - \Delta H_f(C_2H_5OH)$
$-1211 = 3(-286) + 2(-394) - \Delta H_f(C_2H_5OH)$
$\Delta H_f(C_2H_5OH) =$ **<u>–435 kJ mol^{-1}</u>**

Method 2

	ΔH / kJ mol^{-1}	Represents
$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$	–286	$\Delta H_c(H_2)$
$C(s) + O_2(g) \longrightarrow CO_2(g)$	–394	$\Delta H_c(C)$
$C_2H_5OH(l) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(l)$	–1211	$\Delta H_c(C_2H_5OH)$

$2C(s) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_2H_5OH(l)$ $\Delta H_r = \Delta H_f(C_2H_5OH)$

$\Delta H_r = \Delta H_c(\text{reactants}) - \Delta H_c(\text{product})$
$\Delta H_f(C_2H_5OH) = 2\Delta H_c(C) + 3\Delta H_c(H_2) - \Delta H_c(C_2H_5OH)$
$\Delta H_f(C_2H_5OH) = 2(-394) + 3(-286) - (-1211)$
$\Delta H_f(C_2H_5OH) =$ **<u>–435 kJ mol^{-1}</u>**

21 Using $q = mc\Delta T$ **B**

$= (150)(4.18)(11)$

$= 6897\ J = 6.897\ kJ$

$n(MgSO_4) = 9.00 / 120.4$

$= 0.07475$ mol

$\therefore \Delta H_{sol} = -q/n$

$= -6.897 / 0.07475$

$= \underline{-92.3\ kJ\ mol^{-1}}$

22 **D**

- reaction is spontaneous (takes place without any outside interference) $\Rightarrow \Delta G$ is <u>negative</u>
- temperature dropped $\Rightarrow \Delta H$ is <u>positive</u> (endothermic)
- reaction is accompanied by an increase in no. of gaseous particles $\Rightarrow \Delta S$ is <u>positive</u>

23 When a liquid is at its boiling point, the two phases (liquid and gas) in the system are at equilibrium. Hence $\Delta G = 0$. **C**

Since $\Delta G = \Delta H - T\Delta S$ and $\Delta G = 0$,
$\Delta S = \Delta H / T$

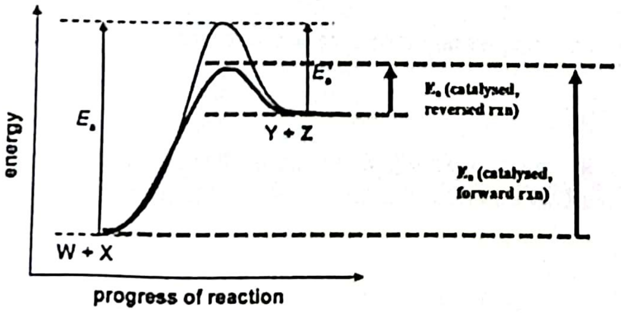
Using ΔH_{vap}(carbon tetrachloride) = +30.0 kJ mol^{-1} and boiling point = 76.7 °C,
ΔS_{vap}(carbon tetrachloride) = +30.0 / (76.7 + 273)
ΔS_{vap}(carbon tetrachloride) = +0.08579 kJ mol^{-1} K^{-1}

Since a wide range of liquids give approximately the same standard entropy change of vaporisation, ΔS_{vap}(carbon tetrachloride) = ΔS_{vap}(decane)

+0.08579 = ΔH_{vap}(decane) / (174 + 273)
ΔH_{vap}(decane) = $\underline{+38.3\ kJ\ mol^{-1}}$

24 **A** Catalyst provides an alternative pathway (mechanism) with a lowered E_a. **B**

B



The addition of a catalyst lowers **BOTH** E_a and E_a'

C and D Correct statements

25 **A** Exothermic reaction occurs via a 2–step mechanism. First step has a higher E_a, hence it is a slow step. **A**

B Exothermic reaction occurs via a 1–step mechanism.

C <u>Endothermic</u> reaction occurs via a 2–step mechanism. Second step has a higher E_a, hence second step is a slow step.

D Exothermic reaction occurs via a 2–step mechanism. Second step has a higher E_a, hence second step is a slow step.

26 Gradient of each curve indicates the rate of reaction (in terms of production of oxygen gas. **C**

1. Adding water decreases the concentration of hydrogen peroxide but not the total number of moles of hydrogen peroxide present. Hence, rate of reaction decreases but the number of moles of oxygen gas produced remains the same. Curve II does not reflect this.
2. Using less manganese(IV) oxide will decrease the rate of reaction but the number of moles of oxygen gas produced remains the same. Again, curve II does not reflect this.
3. Adding <u>some</u> 0.1 mol dm^{-3} hydrogen peroxide will decrease the concentration of hydrogen peroxide (due to increase in the total volume) but increase the number of moles of hydrogen peroxide present. Hence, rate of reaction will decrease but the number of moles of oxygen gas that can be produced will increase.

27 2 Incorrect. All the reactant molecules adsorb on the catalyst surface (heterogeneous catalysis), so all of them form weak bonds with the catalyst. **C**

3 Incorrect. Both carbon monoxide and hydrocarbons react with oxygen and oxidise to carbon dioxide. (Carbon monoxide and hydrocarbons do not react together)

28 1 when [hydrogen peroxide] is **high**, the rate is independent of [hydrogen peroxide] NOT [catalase]! **C**

2 when [hydrogen peroxide] is **high**, the rate is independent of [hydrogen peroxide] as all the active sites in the enzyme (catalase) molecules are occupied by the reactant (hydrogen peroxide) molecules

3 when [hydrogen peroxide] is **low**, the reaction is 1st order w.r.t. hydrogen peroxide as shown in the straight line graph through the origin

29 **C**

$$K_c = \frac{[XY]^2}{[X_2][Y_2]} = \frac{(0.6/V)^2}{(0.2/V)(0.2/V)} = 9$$

30 $N_2(g) + 3H_2 \rightleftharpoons 2NH_3(g)$ $\Delta H < 0$ **A**

When temperature increases, position of equilibrium (P.O.E.) of the above reaction will shift to the left as the reverse endothermic reaction can remove some of the excess heat resulting in a <u>decrease</u> in % NH_3 at equilibrium. (narrow to options **A** & **C**)

When pressure increases, P.O.E. will shift to the right as the forward reaction results in a decrease in no. of moles of gaseous particles (and hence pressure). There will be an <u>increase</u> in % NH_3 at equilibrium.