2020 TJC H2 PROMO MCQ

Section A

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 (OMS).

1 The following shows the deflection of two ions in an electric field.



Which of the following could be J?

- **A** ¹¹B⁺
- **B** ${}^{7}Li^{+}$
- **C** 27 A l^{3+}
- $D ^{24}Mg^{2+}$

2 Use of the Data Booklet is relevant to this question.

Which of the following species do **not** have the same number of unpaired electrons as the others?

Α	P ⁺	В	Cu ³⁺	С	Ca	D	S
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3 Use of the Data Booklet is relevant to this question.

Which of the following have the same number of particles as 23.0 g of ethanol, CH_3CH_2OH , molecules?

- 1 the number of atoms in 2.125 g of ammonia
- 2 the number of molecules in 11.35 dm³ of sulfur dioxide at standard temperature and pressure
- 3 the number of sodium ions in 250 cm³ of 2.0 mol dm⁻³ sodium carbonate
- **A** 1 and 2 **B** 2 and 3 **C** 1, 2 and 3 **D** 2 only

Use of the Data Booklet is relevant to this question.
A vanadium complex has the formula VO(C_xH_yO_z)₂. The percentage composition by mass of the complex is: C, 45.30%; H, 5.29%; O, 30.20%.
What is the value of z?
A 1 B 2 C 4 D 5

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5 The redox reaction between hydrogen sulfide, H₂S, and sulfur dioxide, SO₂, gives elemental sulfur as the only sulfur-containing product.

How many moles of sulfur dioxide react with one mole of hydrogen sulfide?

A $\frac{1}{2}$ **B** $\frac{1}{3}$ **C** 1 **D** 2

6 Tryptophan is an essential amino acid.



Tryptophan

What are the approximate bond angles 1, 2 and 3?

	1	2	3
Α	109.5°	90°	120°
В	120°	109.5°	120°
С	109.5°	90°	107°
D	120°	109.5°	107°

7 The boiling points of ethane and methanal, are as follows:

Compound	Boiling point /°C
CH₃CH₃ Ethane	-88.6°C
O II H ^C H Methanal	-19 °C

Which of the following statements best explains this difference in boiling points?

- A Methanal has a larger electron cloud than ethane.
- **B** Methanal has a strong C=O bond but not ethane.
- **C** Methanal has a permanent dipole but not ethane.
- **D** Methanal exhibits intermolecular hydrogen bonding but not ethane.

8 Hydrazine, $N_2H_4(I)$, reacts with dinitrogen tetraoxide, $N_2O_4(g)$, to form nitrogen gas and water vapour.

$$2N_2H_4(I) + N_2O_4(g) \rightarrow 3N_2(g) + 4H_2O(g)$$

The following data are given.

Substance	ΔH_{f}^{Φ} / kJ mol ⁻¹
$N_2H_4(I)$	+50.6
$N_2O_4(g)$	+9.2
H ₂ O(g)	-241.8

What is the enthalpy change for this reaction?

- A –1077.6 kJ mol⁻¹
- **B** –856.8 kJ mol⁻¹
- C –301.6 kJ mol⁻¹
- **D** –182.0 kJ mol⁻¹
- **9** Sodium burns in oxygen to form Na₂O. Heat energy is given out. The equation for this reaction is shown below.

$$2Na(s) + \frac{1}{2}O_2(g) \rightarrow Na_2O(s)$$

Which of the following statements about the reaction are correct?

- 1 The magnitude of ΔH° for the reaction is equal to twice the bond energy of the Na–O bond.
- **2** ΔH° for the reaction is negative.
- **3** The equation represents the standard enthalpy change of combustion of sodium.
- 4 The equation represents the standard enthalpy change of formation of sodium oxide.
- **A** 1, 2, 3 and 4
- **B** 2, 3 and 4
- **C** 3 and 4
- **D** 2 and 4

10 When 0.04 mol of propan-2-ol, C₃H₈O, was burned under a container of water, only 80% of the heat from the combustion of propan-2-ol was absorbed by the water. It was found that the water was heated from 25°C to 80°C.

Given that the standard enthalpy change of combustion of propan-2-ol is $-2005 \text{ kJ mol}^{-1}$, what is the mass of water heated in this reaction?

[You may use 4.18 J g⁻¹ K⁻¹ for the specific heat capacity of water.]

A 277 g **B** 279 g **C** 349 g **D** 463 g

- **11** Which of the following statements is correct for a reaction in which the equilibrium constant does not change with temperature?
 - A The rate constants for the forward and reverse reactions do not vary with temperature.
 - **B** The activation energy of both forward and reverse reactions are zero.
 - **C** There are equal numbers of moles of reactants and products.
 - **D** The enthalpy change for the reaction is zero.
- **12** A sample of (NH₄)₂SO₄(s) was placed in a 1 dm³ enclosed vessel and allowed to dissociate at 330°C as follows:

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 $(NH_4)_2SO_4(s) \rightleftharpoons 2NH_3(g) + H_2SO_4(g)$

The value of K_c is 2.57 x 10⁻⁵.

What will be the concentration of H_2SO_4 at equilibrium?

Α	0.00358	В	0.0186
С	0.0295	D	0.0371

13 The decomposition of a sample of hydrogen peroxide in the presence of manganese (IV) oxide is as follows.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

A study of the rate of this reaction gave the following results.

Time after the start of	Volume of O ₂ produced / cm ³
reaction / s	
0.0	0
10.0	27
20.0	50
30.0	68
40.0	75
50.0	100
60.0	100

Which conclusions can be drawn about the kinetics of this reaction?

- **1** The half-life is 20 s.
- 2 The reaction is first order with respect to $[H_2O_2]$.
- **3** The overall reaction is second order.

Α	2 only	В	1 and 2	С	1 and 3	D	2 and 3
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14 For a reversible reaction, the rate constants for the forward reaction and reverse reactions are k_f and k_b respectively, while K_c is the equilibrium constant.

Which of the following statements is true of the effect of a catalyst on k_f, k_b and K_c?

	k _f	k₀	Kc
Α	increase	decrease	no effect
В	increase	decrease	increase
С	increase	increase	no effect
D	no effect	no effect	increase

15 When a sample of gas at a constant temperature is compressed, pressure increases from 20 atm to 50 atm and the volume decreases from 96 cm³ to 46 cm³.

Which of the following statements best explains this behaviour?

- A The gas particles have significant volume compared to the volume of the container.
- **B** There are significant intermolecular forces of attraction between the gas particles.
- **C** The collisions between the gas particles are not perfectly elastic.
- **D** The gas particles are in a state of continuous random motion.
- **16** The following diagram shows the contents of three vessels which are joined together by a connecting tube of volume, V dm³ in which air has been removed.



After the valves of the vessels were opened, the final pressure at 30°C is measured to be 0.68 atm. The gases do not react with each other.

If all the vessels and connecting tube are maintained at 30°C, what is the volume, V, of the connecting tube?

Α	0.037 dm ³	В	0.074 dm ³
С	0.392 dm ³	D	5.07 dm ³

17 Which of the following is always true for an electrophile?

- 1 It accepts a pair of electrons.
- 2 It is a cation.
- 3 It is attracted to electron rich sites.

Α	3 only	В	1 and 2	С	1 and 3	D	2 and 3
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18 Methane reacts with excess chlorine in the presence of ultraviolet light.

Which of the following product will not be formed?

- **A** H₂
- B HCl
- $C = CH_2Cl_2$
- **D** CH_3CH_2Cl
- **19** A sample of propene was reacted with bromine dissolved in aqueous hydrochloric acid.

Which of the following products will not be formed in the reaction?



20 Prismane is a polycyclic hydrocarbon which is an isomer of benzene.



Prismane

When prismane undergoes reaction with bromine gas under uv light, it forms a compound $C_6H_4Br_2.$

How many constitutional isomers would this compound have?

A 2 **B** 3 **C** 5 **D** 6

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SECTION B (STRUCTURED)

Answer all the questions in the spaces provided.

1 (a) In air polluted with nitrogen oxides, the following reaction is observed.

 $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$

The initial rate of this reaction was measured at different initial concentrations of O_2 and NO. The following results were obtained.

Evet	Initial reactant cor	Initial Rate / mol dm ⁻³ s ⁻¹	
Expl	[O ₂] [NO]		
1	1.10 x 10 ⁻²	1.30 x 10 ⁻²	3.20 x 10 ⁻³
2	2.20 x 10 ⁻²	1.30 x 10 ⁻²	6.40 x 10 ^{−3}
3	2.20 x 10 ^{−2}	2.60 x 10 ⁻²	25.6 x 10 ^{−3}
4	1.10 x 10 ⁻²		28.8 x 10 ^{−3}



(i) Deduce the order of reaction with respect to O₂. [1]
(ii) Deduce the order of reaction with respect to NO. [1]
(iii) Construct the rate equation for this reaction. [1]
(iv) Complete Table 1 for experiment 4. [1]

(b) At 1500K, the reaction between nitrogen monoxide and oxygen occurs at an equilibrium.

In an experiment, 0.46 mol of nitrogen monoxide and 0.35 mol oxygen are placed in a 2 dm³ sealed container and allowed to reach equilibrium at 1500K. At equilibrium, 0.02 mol of nitrogen dioxide is formed.

 $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

(i) Write an expression for K_c . Calculate the value for K_c and state its units. [3]

(ii) Using *Le Chatelier's Principle*, explain the effect on the composition of the equilibrium mixture when the volume of the container is increased. [2]

[Total: 9]

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2 (a) Ammonia is formed from hydrogen and nitrogen.

$$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$$

In the production of ammonia, iron is used as a catalyst to speed up the rate of reaction.

(i) Using an appropriate sketch of Boltzmann distribution, explain why the addition of iron catalyst speeds up the rate of formation of ammonia. [3]

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(ii) Identify the type of catalyst and outline the mode of action of the iron catalyst in this reaction. [2]

(iii) To produce the iron catalyst, finely ground iron powder is repeatedly heated and cooled under specific conditions to give a highly porous solid. Suggest a reason for the iron catalyst being produced as a porous solid. [1] (b) Iodine monochloride, ICl, is an interhalogen compound commonly used in organic synthesis. It undergoes addition reaction with cyclohexene to form 1-chloro-2-iodocyclohexane. $\mathbf{C}l$

1-chloro-2-iodocyclohexane

- Suggest why ICl reacts with cyclohexene more readily than the pure
- [1]

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(i)

halogens Cl₂, Br₂ and I₂.

1-chloro-2-iodocyclohexane can be converted to cyclohexa-1,3-diene.



(ii) Identify the type of reaction and give the reagents and conditions required for this conversion. [2]

Type of reaction:	
21	

Reagent and conditions :

(iii) When cyclohexa-1,3-diene is heated with excess acidified potassium manganate(VII), a single organic product F is formed. Draw the structure of F.

[Total: 10]

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3 (a) The figure below shows a sketch of the logarithm of the first ten ionisation energies of an element Y.



log (Ionisation Energy)



(ii) The second ionisation energies of the eleven consecutive elements (including element Y) from Period 2 and Period 3 are shown below:

Second ionisation energy



[1]

(iii) Explain why the second ionisation energy of element **J** is lower than that of element **B**. [2]



(b) Tin is another element in the Periodic Table. In order to determine the percentage purity of tin, 2.50 g of a tin-containing metal ore was dissolved in 50 cm³ of excess acid. The solution was found to contain tin(II) ions.

Potassium nitrate, KNO_3 , was then added to the solution to convert all the tin(II) ions to tin(IV) ions.

10.0 cm³ of this resulting tin(IV) solution required 22.00 cm³ of 0.120 mol dm⁻³ sodium thiosulfate solution for reaction as follows:

$$2S_2O_3^{2-}$$
 + Sn^{4+} \rightarrow Sn^{2+} + $S_4O_6^{2-}$

(i) Given that NO_3^- was reduced to NO_2^- , write an equation for the reaction between potassium nitrate and tin(II) ions. [1]

(ii) Calculate the amount of tin in the tin-containing metal ore.

[2]

(iii) Hence, calculate the percentage purity of tin in the tin-containing metal ore. [1]

[Total: 8]

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Simple propargylic ethers are important reagents and building blocks in 4 (a) organic synthesis. An example of a simple propargylic ether is compound X below.



Compound X

(i) State the hybridisation of carbon 1 and carbon 2 in compound X. [1]

Carbon 2 :	
State the share and suggest a value for the hand angle around the	
carbon 1 and the oxygen atom in compound X .	[2]
Carbon 1:	
Oxygen:	

(b) Compound X is a liquid under standard conditions.

During combustion, compound X, C_4H_6O , reacts with excess oxygen to produce carbon dioxide and water.

(i) Write a balanced equation, including state symbols, for the standard enthalpy change of combustion of compound X.

(ii)

Carbon 1

(ii) By using appropriate bond energy values from the Data Booklet, calculate the enthalpy change of combustion of compound X.

The theoretical value of the standard enthalpy change of combustion of compound **X** was found to be -2444 kJ mol⁻¹.

(iii) Apart from bond energies values being average values, suggest a reason for the difference between the enthalpy change of combustion calculated in (b)(ii) and the theoretical value given.

[1]

(iv) The enthalpy change of vaporisation of water was found to be $+41.0 \text{ kJ mol}^{-1}$.

Using the theoretical value of the standard enthalpy change of combustion of compound **X** and your answer in **(b)(ii)** together with the above information, calculate the enthalpy change of vaporisation, ΔH_{vap} , of compound **X**, C₄H₆O.

 $C_4H_6O(I) \longrightarrow C_4H_6O(g)$ ΔH_{vap} [2]

(c) An example of electron-rich dienes is compound **Y** as shown below:



Compound \boldsymbol{Y}

(i) State and explain the type of stereoisomerism compound Y exhibits. [1]

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(ii)	State the total number of stereoisomers and draw the structures of two	
	of the isomers.	[2]

Total number of stereoisomers =

[Total: 13]

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Section C Free Response

Answer **all** the questions

- 1 Coal is a highly polluting fuel as it produces sulfur dioxide during combustion. Coal gasification is a multi-step process in which sulfur in coal is removed as hydrogen sulfide gas, H₂S.
 - (a) In presence of air, hydrogen sulfide is used for the production of sulfur via the *Claus* [1] *process.* Sulfur dioxide and steam are obtained as by-products.

Write a balanced equation for the reaction.

(b) One of the steps in coal gasification involves reacting coal with superheated steam to produce "water gas", an equimolar mixture of hydrogen gas and carbon monoxide. 1 mol water gas contains 0.5 mol of hydrogen gas and 0.5 mol of carbon monoxide.

 $C(s) + H_2O(g) \rightarrow CO(g) + H_2(g)$

The enthalpy change of combustion of the following substances are given.

Substance	$\Delta H_c / kJ mol^{-1}$	
CH_4	-890	
H_2	-242	
CO	-283	

- (i) Define the term *standard enthalpy change of combustion*.
- (ii) Calculate the enthalpy change of combustion of water gas.
- (iii) Using information in (b) and your answer in (b)(ii), calculate the volumes of methane gas and water gas under room conditions required to <u>each</u> produce 1500 kJ of energy on combustion.
- (iv) Methane is a major component of natural gas. With reference to your answers in
 (b)(iii) and other considerations, suggest two advantages of using natural gas rather than water gas.

[1]

[1]

[2]

[2]

..... (c) Methanol and methane can also be produced from coal gasification. (i) Using the information in (b) and the following data, determine the enthalpy change of combustion of methanol with aid of an energy cycle. [3] $CO(g) + 2H_2(g) \rightarrow CH_3OH(I)$ $\Delta H = -128 \text{ kJ mol}^{-1}$ (ii) Although methane and water gas release large amount of energy on combustion, the large volumes needed limits their usage as fuels as compared to liquid fuels like methanol. With reference to structure and bonding, explain two reasons why methanol exists as a liquid while methane is a gas. [3]

(d)	The (produ	Claus process is used for the production of elemental sulfur which can be used to uce sulfuric acid.	
	(i)	Define the term standard enthalpy change of neutralisation.	[1]
	(ii)	When 30 cm ³ of 1.0 mol dm ⁻³ NaOH(aq) is neutralised with an equal volume of 1.0 mol dm ⁻³ H ₂ SO ₄ (aq), the temperature of the mixture rose by 6.8 °C.	
		Calculate the number of moles of water formed.	[1]
	(iii)	Hence, determine the temperature change if 15 cm ³ of 2.0 mol dm ^{-3} NaOH(aq) is reacted with an equal volume of 2.0 mol dm ^{-3} H ₂ SO ₄ (aq). Show your working clearly.	[2]
	(iv)	The reaction mixture in (d)(ii) is made up to a 100 cm ³ standard solution. 25 cm ³ of the resulting solution is titrated with a standard solution of KOH(aq). The titre value is 18.60 cm^3 .	[3]
		Calculate the concentration of the KOH(aq) solution.	

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2 (a) 3-methylbut-1-ene is a colourless, volatile liquid which reacts with HBr(g).



3-methylbut-1-ene

- (i) Name and describe the mechanism of this reaction. Show relevant lone pairs and [4] dipoles, and use curly arrows to indicate movement of electron pairs.
- (ii) Explain why a pair of stereoisomers is formed. Draw the pair of stereoisomers. [3]
- (iii) State if the product mixture is optically active.
- (iv) Suggest the structure of the organic product formed if 3-methylbut-1-ene is reacted with liquid bromine. State the observation for this reaction. [2]
- (v) Describe and explain how the entropy of 3-methylbut-1-ene will change upon vaporisation. [1]

[1]

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- (b) (i) Calculate the pressure exerted by 1 mole of CH₄ in a 0.25 dm³ container at 25 °C, given that it obeys the ideal gas law.
 - (ii) The van der Waals equation shown below is often used to account for the discrepancies between a real gas and an ideal gas.

$$(p + \frac{n^2 a}{V^2})(V - nb) = nRT$$

where p: actual pressure in Pa

V: volume of the container in m³

T: temperature in Kelvin

n: amount of substance

R: molar gas constant

a and b: van der Waals constants

Using the van der Waals equation, calculate the actual pressure, p in Pa, exerted by 1 mole of CH₄ in a 0.25 dm³ container at 298K. Given that the van der Waals constants for CH₄ are:

 $a = 0.228 \text{ Pa m}^6 \text{ mol}^{-2}$

b = 4.28 x 10⁻⁵ m³ mol⁻¹

(iii) Suggest a reason for the difference between the two values obtained in (b)(i) and (b)(ii).

[2]

[1]

[1]

(c) Sodium chloride and silver chloride are two simple salts and their solubilities in water are

Salt	$\Delta H_{\text{lattice}}^{\Theta} / \text{ kJ mol}^{-1}$	ΔH_{soln}^{Θ} / kJ mol ⁻¹	ΔS_{soln}^{Θ} / J mol ⁻¹ K ⁻¹
NaCl	-779	x	+43.2
AgCl	-890	+65.7	+34.3

being considered in this question.

Table 2

- (i) Given that the hydration energies of gaseous sodium ion and gaseous chloride ion are -390 kJ mol^{-1} and -384 kJ mol^{-1} respectively, determine the ΔH_{soln}^{e} , *x*, of sodium chloride.
- (ii) Explain why the hydration energy of gaseous magnesium ion is of a larger magnitude as compared to that of gaseous sodium ion.
- (iii) Use your answer in (c)(i) and values given in the Table 2 above to calculate the ΔG_{soln}° for **each** of the salts and hence deduce the solubility of the salts in water at 25 °C.

[1]

[1]

[3]

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[Total: 20]

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