15/15 27/28 excellent

Chemistry HL 2018-2020

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Kinetics and before

Time Allowed: 65 min

1. Which step in a multi-step reaction is the rate determining step?

A. The first step

B. The last step

C. The step with the lowest activation energy

(D.) The step with the highest activation energy

2. The rate expression for a reaction is shown below.

$$\text{rate} = k[A]^2[B]^2$$

Which statements are correct for this reaction?

I. The reaction is second order with respect to both A and B. ✓

II. The overall order of the reaction is 4. ✓

III. Doubling the concentration of A would have the same effect on the rate of reaction as doubling the concentration of B. ✓

A. I and II only

B. I and III only

C. II and III only

(D.) I, II and III

(2)

3. The reaction between NO_2 and F_2 gives the following rate data at a certain temperature. What is the order of reaction with respect to NO_2 and F_2?

$[NO_2]$/mol dm^{-3}	$[F_2]$/mol dm^{-3}	Rate /mol dm^{-3} min^{-1}
0.1	0.2	0.1
0.2	0.2	0.4
0.1	0.4	0.2

	NO_2 order	F_2 order
A.	first	first
B.	first	second
C.	second	first
D.	second	second

$[NO_2]^2 [F_2]$.

4. The rate expression for a particular reaction is

Rate = k[P][Q]

Which of the units below is a possible unit for k?

A. $mol^{-2}\ dm^6\ min^{-1}$

B. $mol^{-1}\ dm^3\ min^{-1}$

C. $mol\ dm^3\ min^{-1}$

D. $mol^{-2}\ dm^{-6}\ min^{-1}$

$M/s = k \cdot M^2$

$k = M^{-1} s^{-1}$

$= mol^{-1}\ dm^3 \cdot s^{-1}$

5. The mechanism of a reaction is

$$XY_2 + XY_2 \rightarrow X_2Y_4$$
$$X_2Y_4 \rightarrow X_2 + 2Y_2$$
$$X_2 + Y_2 \rightarrow 2XY$$

What is the overall equation for the reaction?

$2XY_2 \rightarrow X_2 + 2Y_2$.

$2XY_2 \rightarrow 2XY + Y_2$.

A. $X_2Y_4 \rightarrow 2XY_2$

B. $2XY_2 \rightarrow X_2 + 2Y_2$

(C.) $2XY_2 \rightarrow 2XY + Y_2$

D. $X_2Y_4 \rightarrow 2XY + Y_2$

6. The activation energy, of a reaction can be obtained from the rate constant, k, and the absolute temperature, T. Which graph of these quantities produces a straight line?

A. k against T

B. k against $\frac{1}{T}$

$k = A e^{-\frac{Ea}{RT}}$

C. $\ln k$ against T

$\ln k = \ln A - \frac{Ea}{RT}$

(D.) $\ln k$ against $\frac{1}{T}$

7.

Which conditions are required for the reaction between two molecules?

I. a collision
II. $E \geq E_a$
III. proper orientation

A. I and II only

B. I and III only

C. II and III only

(D.) I, II and III

3

8.

Which statement is correct about a catalyst?

A. It decreases the activation energy of the forward reaction but not the reverse.

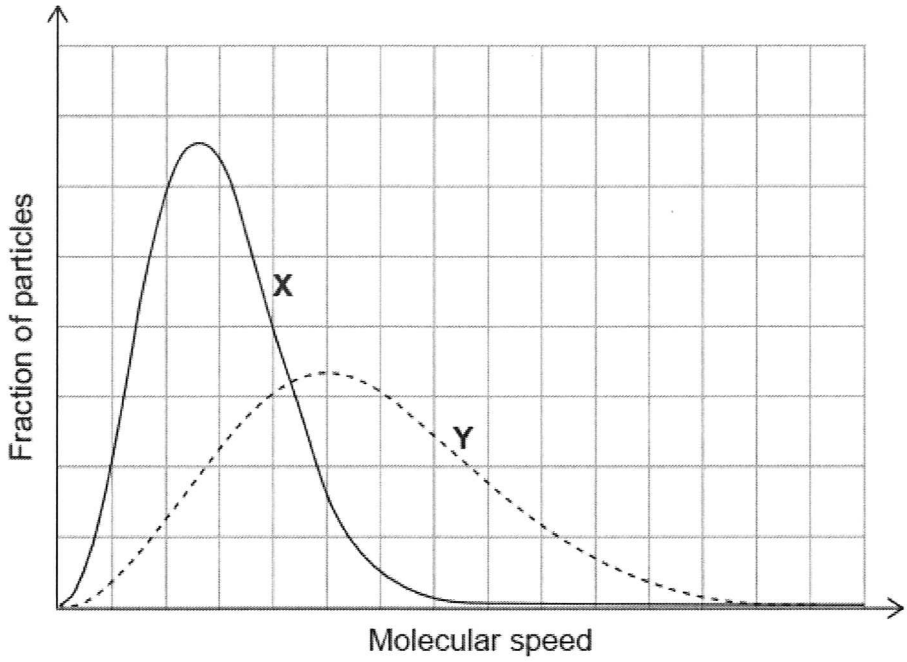
B. It increases the proportion of products to reactants in an equilibrium.

C. It decreases the enthalpy change of the reaction.

(D.) It changes the mechanism of the reaction.

9.

The same amount of two gases, **X** and **Y**, are in two identical containers at the same temperature. What is the difference between the gases?



(A.) **X** has the higher molar mass.

B. **Y** has the higher molar mass.

C. **X** has the higher average kinetic energy.

D. **Y** has the higher average kinetic energy.

10.

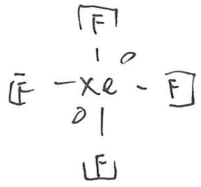
Which species has a square planar molecular geometry?

A. SF_4

B. XeF_4

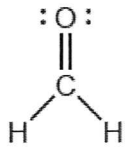
C. CF_4

D. PF_4^+



11.

What is the hybridization of carbon and oxygen in methanal?



	Hybridization of C	Hybridization of O
A.	sp^2	sp^2
B.	sp^2	sp
C.	sp	sp^2
D.	sp^3	sp^3

12.

What volume of carbon dioxide, $CO_2(g)$, can be obtained by reacting $1\,dm^3$ of methane, $CH_4(g)$, with $1\,dm^3$ of oxygen, $O_2(g)$?

$$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$$

A. $0.5\,dm^3$

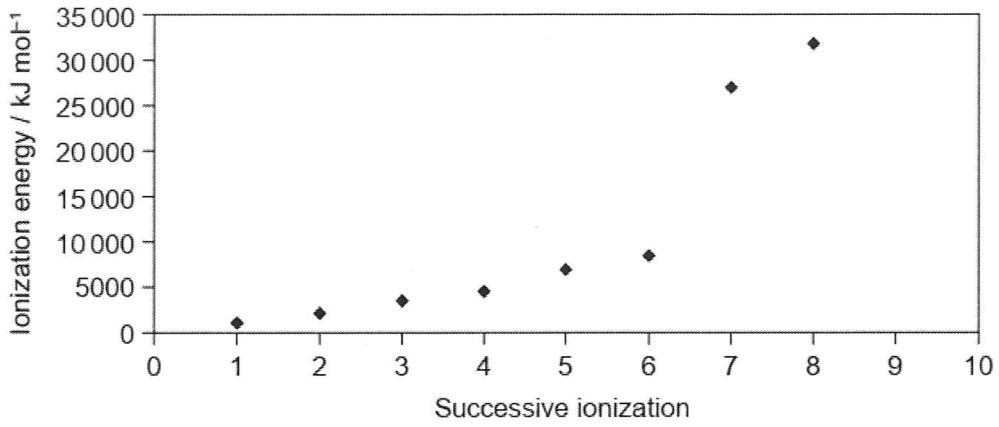
B. $1\,dm^3$

C. $2\,dm^3$

D. $6\,dm^3$

13.

Which element is represented by the first eight successive ionization energies on the graph?



A. Mg

B. S

C. Cl

D. Ar

14.

How should a measurement of 5.00 g from a balance be recorded?

A. 5.00 ± 0.1 g

B. 5.00 ± 0.01 g

C. 5.00 ± 1 g

D. 5.00 ± 0.001 g

15.

What is the volume of gas when the pressure on 100 cm^3 of gas is changed from 400 kPa to 200 kPa at constant temperature?

A. 50.0 cm^3

B. 100 cm^3

C. 200 cm^3

D. 800 cm^3

$P_1 V_1 = \vec{n} \vec{R} \vec{T}$

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Section B

1.

The compound iodine chloride, ICl, reacts with hydrogen to form iodine and hydrogen chloride.

(i) Deduce the equation for this reaction.

(1)

$2ICl + H_2 \rightarrow I_2 + 2HCl$ 1

(ii) The kinetics of this reaction were studied at a certain temperature, when all the reactants and products were in the gas phase. The table shows the initial rate of reaction for different concentrations of reactants.

Experiment	[ICl] / mol dm^{-3}	[H_2] / mol dm^{-3}	Initial rate / mol dm^{-3} s^{-1}
1	0.100	0.0500	5.00×10^{-3}
2	0.200	0.0500	1.00×10^{-2}
3	0.200	0.0250	2.50×10^{-3}

Deduce and explain the order of reaction with respect to ICl and to H_2.

(4)

① In Exp 1 & 2, [ICl] doubled, [H_2] unchanged. ✓

R_I doubled. [ICl] is first order. ✓

② In Exp 2 & 3, [ICl] unchanged, [H_2] decreased a half. ✓

R_I decreased to a quarter. [H_2] is second order. ✓

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(iii) Write the rate expression for the reaction.

(1)

$r = k\,[ICl]\,[H_2]^2$. ✓ 1

$\frac{5\times10^{-3}\ M/s}{2.5\times10^{-4}\ M^3} = 20\ M^{-2}\,s^{-1}$

$= 20\ mol^{-2}\,dm^6\,s^{-1}$

(iv) Use information from Experiment 1 to determine the value, with units, of the rate constant for the reaction.

$(5\times10^{-2})^2 \rightarrow 2.5\times10^{-4}$

(2)

$5.00\times10^{-3}\ M/s = k \cdot 0.1\ M \cdot (0.05\ M)^2$

$k = 20\ mol^{-2}\,dm^6\,s^{-1}$. ✓ 2

8

(v) Determine the rate of reaction when the concentrations of reactants in Experiment 1 are both doubled.

$R' = k \cdot (2[ICl])(2[H_2])^2 = k \cdot 8[ICl][H_2]^2 = 8R_1$ **(1)**

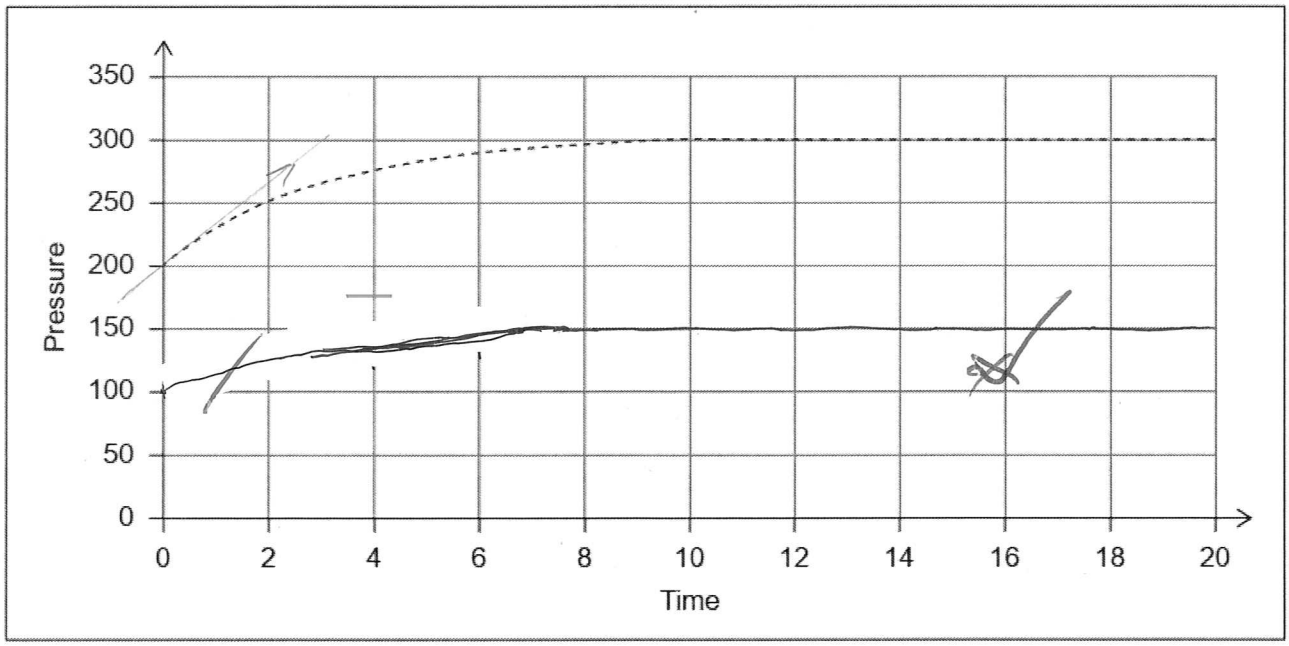
$\therefore R' = 8 \times 5.00 \times 10^{-3} = 4.00 \times 10^{-2}$ mol dm^{-3} s^{-1}

2. The thermal decomposition of dinitrogen monoxide occurs according to the equation:

$$2N_2O(g) \rightarrow 2N_2(g) + O_2(g)$$

The reaction can be followed by measuring the change in total pressure, at constant temperature, with time.

The x-axis and y-axis are shown with arbitrary units.



(a) Explain why, as the reaction proceeds, the pressure increases by the amount shown. [2]

Reactant : Products = 2mol gas : 3mol gas.
$PV = nRT$, n changed while V, R, T is unchanged, so the pressure increase to 150%. (200 → 300)

2

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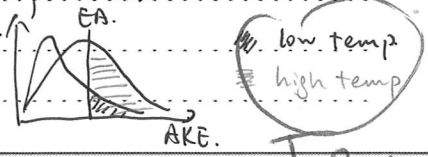
(b) Outline, in terms of collision theory, how a decrease in pressure would affect the rate of reaction. [2]

Decrease in temperature will decrease the frequency of both overall collisions and successful collisions, as the decrease of the average kenetic energy of the gas particles lowers the fraction above the activation energy



pressure doesn't change kinetic energy

Temp was not changed

1

(c) This decomposition obeys the rate expression:

$$-\frac{d[N_2O]}{dt} = k[N_2O]$$

(i) Deduce how the rate of reaction at $t = 2$ would compare to the initial rate. [1]

It's first order, so half-time remains constant. According to the graph, at t=2, $[N_2O]$ is one-half remaining so the rate would be 50% of RI as well.

1

(ii) It has been suggested that the reaction occurs as a two-step process:

Step 1: $N_2O(g) \rightarrow N_2(g) + O(g)$

Step 2: $N_2O(g) + O(g) \rightarrow N_2(g) + O_2(g)$

Explain how this could support the observed rate expression. [2]

IC: Step 1 is slow while step 2 is fast, so step 1 with rate expression $r = k[N_2O]$ is the rate-determining step, and determines the overall rate expression.

(If step 2 is slow, then overall rate expression would be second order.)

2

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(d) The experiment is repeated using the same amount of dinitrogen monoxide in the same apparatus, but at a lower temperature.

Sketch, on the axes in question 2, the graph that you would expect. [2]

(e) The experiment gave an error in the rate because the pressure gauge was inaccurate. Outline whether repeating the experiment, using the same apparatus, and averaging the results would reduce the error. [1]

It won't. Systemmatic errors can only be reduced by calibration, trials repetition only deals with random errors.

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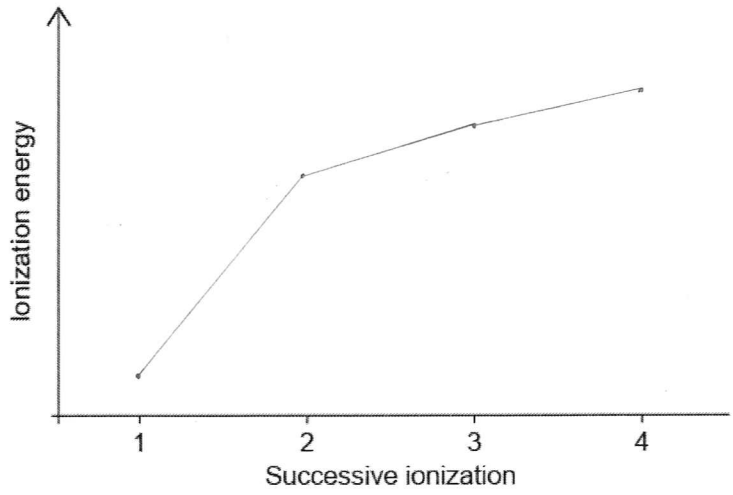
3. This question is about sodium and its compounds.

(a) Plot the relative values of the first four ionization energies of sodium. [1]



(b) Outline why the alkali metals (group 1) have similar chemical properties. [1]

They have 1 valence electron and are readily available to donate them to electrophiles.

(c) Describe the structure and bonding in solid sodium oxide. Na_2O. [2]

Sodium is a metal element with small electronegativity while oxygen is a non-metal element with b.g. electronegativity. The difference of electronegativity is large enough for ionic bonding to take place. Solid Na_2O is the lattice structure of Na^+ and O^{2-} hold together by the attraction between the cation and the anion.

electrostatic

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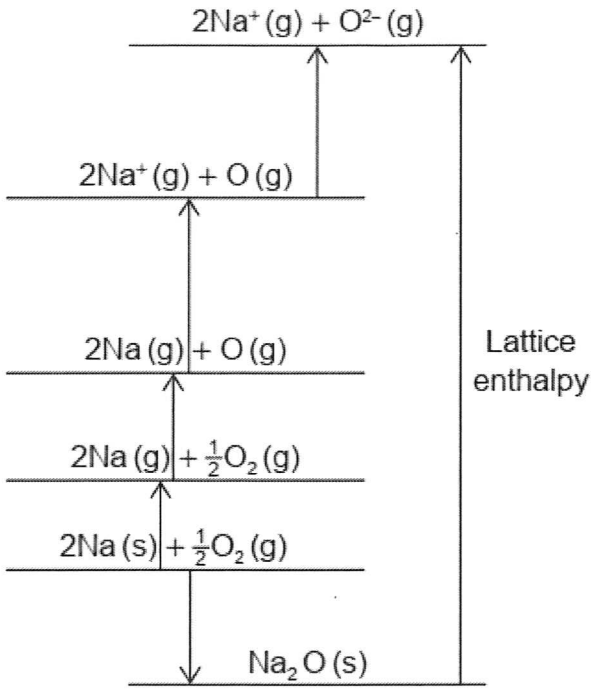
(d) The Born-Haber cycle for sodium oxide is shown (not to scale).



(i) Calculate values for the following changes using section 8 of the data booklet. [2]

$\Delta H_{atomisation}$ (Na) = 107 kJ mol^{-1}

$\Delta H_{atomisation}$ (O) = 249 kJ mol^{-1}

$\frac{1}{2}O_2(g) \rightarrow O^{2-}(g)$:

$\Delta H = \Delta H_{atom}(O) + \Delta H_{1st\ EA}(O) + \Delta H_{2nd\ EA}(O)$

$= 249\ kJ/mol - 141\ kJ/mol + 753\ kJ/mol$

$= 861\ kJ/mol$

$Na(s) \rightarrow Na^+(g)$:

$\Delta H = \Delta H_{atom}(Na) + \Delta H_{1st\ ion}(Na)$

$= 107\ kJ/mol + 496\ kJ/mol$

$= 603\ kJ/mol$

2

(ii) The standard enthalpy of formation of sodium oxide is $-414\,kJ\,mol^{-1}$. Determine the lattice enthalpy of sodium oxide, in $kJ\,mol^{-1}$, using section 8 of the data booklet and your answers to (d)(i). [2]

(If you did not get answers to (d)(i), use $+850\,kJ\,mol^{-1}$ and $+600\,kJ\,mol^{-1}$ respectively, but these are not the correct answers.)

$\Delta H_{lat}(Na_2O) = \Delta H_{d(i)} - \Delta H_{form}(Na_2O)$.

$= (861 + 2 \times 603)\,kJ/mol - (-414)\,kJ/mol$

$= 2481\,kJ/mol$

2

(iii) Justify why K_2O has a lower lattice enthalpy (absolute value) than Na_2O. [1]

$F = k \cdot \frac{q_1 q_2}{r^2}$ according to Coulomb's Law. q_1 q_2 is unchanged for both cases, but potassium is larger, creating a longer distance(r), that leads to a weaker force between the cation and the anion. As less energy is required to break the lattice, the lattice enthalpy is lower.

1

3