24/24

Name: Jerry Jiang

2018-2019 CHEMISTRY HL

END OF YEAR EXAM

PAPER 1

Time Allowed: 40 minutes

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, circle the answer you consider to be the best and indicate your choice on the answer sheet provided.
- If you decide to change your answer put a cross through the incorrect answer and circle you new choice for the correct answer.
- Paper 1 has a maximum mark of *[25 marks]*.
- A copy of the periodic table is provided for Paper 1
- Calculators are **not allowed** for Paper 1

1. Which changes of state are endothermic processes?

I. Condensing
II. Melting
III. Subliming

A. I and II only
B. I and III only
(C.) II and III only
D. I, II and III

2. What is the sum of the coefficients when the equation for the combustion of ammonia is balanced using the smallest possible whole numbers?

$$4\ NH_3(g) + 3\ O_2(g) \rightarrow 2\ N_2(g) + 6\ H_2O(g)$$

A. 6
B. 12
C. 14
(D.) 15

3. 5.00 g of calcium carbonate, when heated, produced 2.40 g of calcium oxide. Which is the correct expression for the percentage yield of calcium oxide? ($M_r(CaCO_3) = 100; M_r(CaO) = 56.$)

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

A. $\frac{56 \times 5.00 \times 100}{2.40}$

(B.) $\frac{2.40 \times 100 \times 100}{56 \times 5.00}$

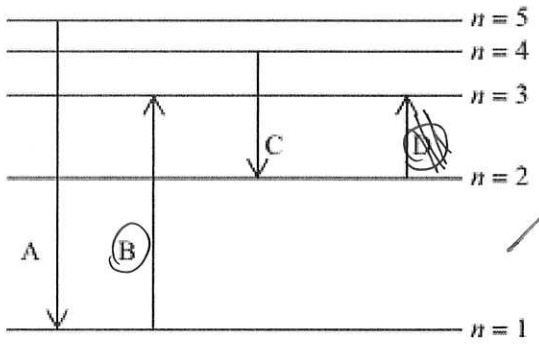
C. $\frac{56 \times 5.00 \times 100}{2.40 \times 100}$

D. $\frac{2.40 \times 100}{56 \times 5.00}$

$\frac{2.4}{5 \cdot \frac{56}{100}}$

3

4. Which electronic transition would absorb the radiation of the shortest wavelength?



5. Which is the electron configuration of the ion Fe^{2+}?

A. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

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

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

D. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

6. Which element is in group 2?

	1st ionization energy / kJ mol^{-1}	2nd ionization energy / kJ mol^{-1}	3rd ionization energy / kJ mol^{-1}	4th ionization energy / kJ mol^{-1}
A.	1402	2856	4578	7475
B.	590	1145	4912	6474
C.	403	2632	3900	5080
D.	578	1817	2745	11578

7. Which element is in the f-block of the periodic table?

A. Be

B. Ce

C. Ge

D. Re

8. Which property increases down group 1 of the periodic table?

A. Melting point ↓

B. First ionization energy ↓

C. Atomic radius ↑

D. Electronegativity ↓

9. What is the formula of calcium nitride?

A. Ca_3N_2

B. Ca_2N_3

C. $Ca(NO_2)_2$

D. $Ca(NO_3)_2$

10. Which compounds have an ionic lattice structure in the solid state?

I. Silicon dioxide SiO_2.

II. Sodium fluoride NaF

III. Ammonium nitrate NH_4NO_3.

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

11. Which is the best description of ionic bonding?

(A) Electrostatic attraction between oppositely charged ions

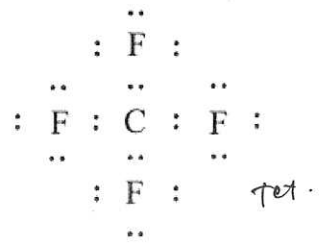
B. Electrostatic attraction between positive ions and electrons ✗ met.

C. Electrostatic attraction of nuclei towards shared electrons in the bond between the nuclei cov.

D. Electrostatic attraction between nuclei ?? BS.

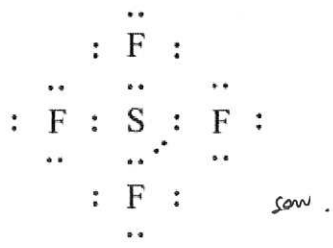
12. Which species has a square planar shape?

A.



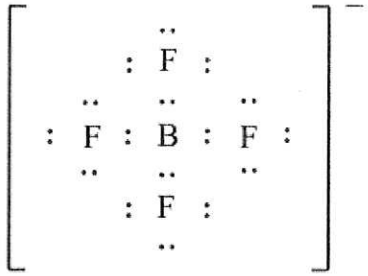
tet.

B.



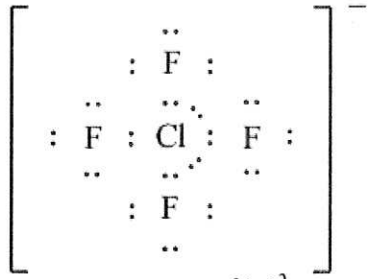
sow.

C.



tet.

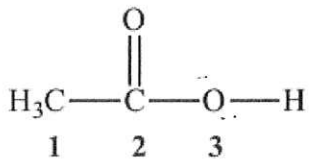
(D.)



sq. pl.

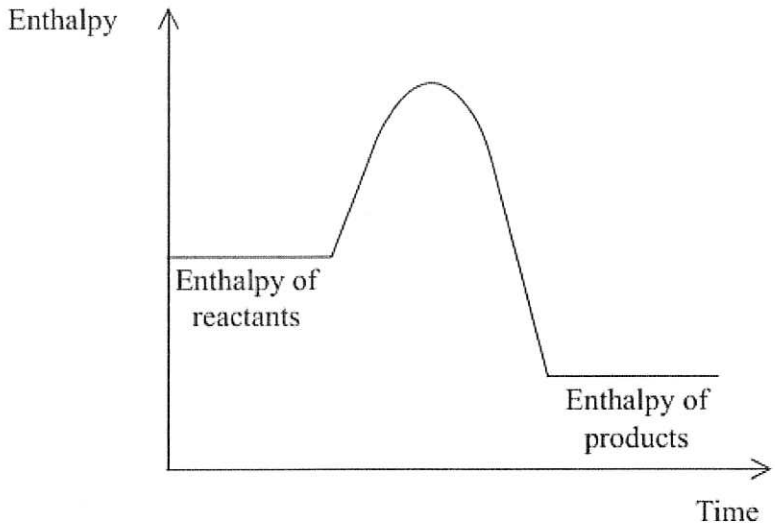
(2)

13. What are the hybridizations of the atoms labelled **1**, **2** and **3** in the molecule below?



	1	2	3
A.	sp^2	sp^2	sp
B.	sp^3	sp^2	sp^3
C.	sp^2	sp	sp^3
D.	sp^3	sp^2	sp

14. Which statement is correct for the enthalpy level diagram shown?



A. The reaction is exothermic and the products are more stable than the reactants.

B. The reaction is exothermic and the sign of the enthalpy change is positive.

C. The reaction is endothermic and the sign of the enthalpy change is negative.

D. The reaction is endothermic and the products are more stable than the reactants.

15. Which process is endothermic?

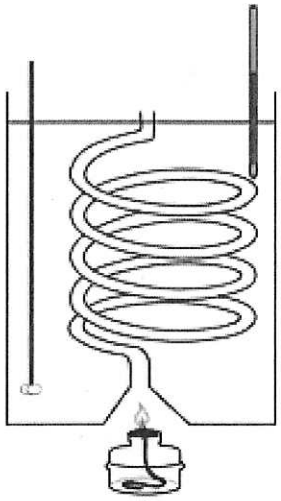
A. $2C_4H_{10}(g) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$

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

C. $H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(l)$

D. $NH_3(g) \rightarrow NH_3(l)$

16. When 0.46 g of ethanol is burned under a water-filled calorimeter, the temperature of 500 g of water is raised by 3.0 K. (Molar mass of ethanol = 46 g mol^{-1}; specific heat capacity of water = 4.18 J g^{-1} K^{-1}; $q = mc\Delta T$.)



What is the expression for the enthalpy of combustion, ΔH_c, in kJ mol^{-1}?

A. $-\dfrac{500 \times 4.18 \times 3.0 \times 46}{0.46}$

B. $-\dfrac{500 \times 4.18 \times (273 + 3.0) \times 46}{0.46 \times 1000}$

C. $-\dfrac{500 \times 4.18 \times 3.0 \times 46}{0.46 \times 1000}$

D. $-\dfrac{0.46 \times 1000}{500 \times 4.18 \times 3.0 \times 46}$

2

17. Given the following information, what is the standard enthalpy of formation, $\Delta H^{\ominus}_{f}$, of methane?

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = E$ kJ

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$ $\Delta H = F$ kJ

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H = G$ kJ

A. E + F + G

B. E + F – G

C. E + 2F + G

D. E + 2F – G

18. Which combination has the most endothermic lattice enthalpy?

	Radius of positive ion / nm	Radius of negative ion / nm	Charge on positive ion	Charge on negative ion
A.	0.100	0.185	2+	2–
B.	0.102	0.180	1+	1–
C.	0.149	0.180	1+	1–
D.	0.100	0.140	2+	2–

19. In which reaction is the value of ΔS positive?

A. $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

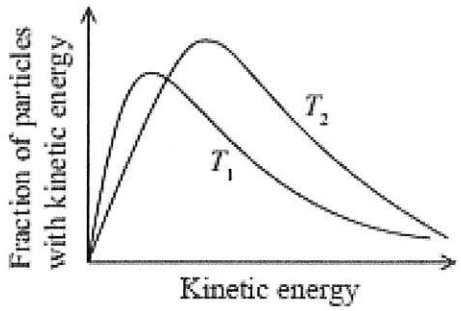
B. $H_2O(g) \rightarrow H_2O(s)$

C. $2KI(aq) + Pb(NO_3)_2(aq) \rightarrow PbI_2(s) + 2KNO_3(aq)$

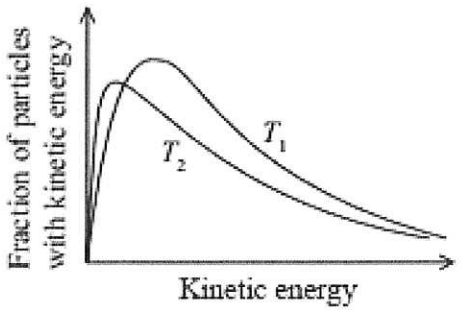
D. $2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$

20. Which graph shows the Maxwell-Boltzmann energy distribution of a same amount of a gas at two temperatures, where T_2 is greater than T_1?

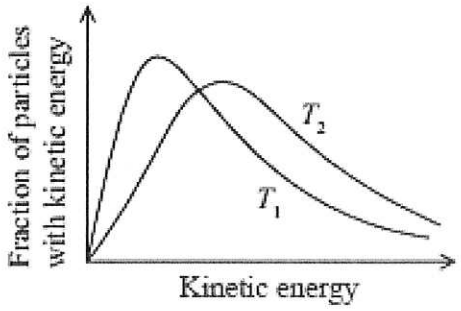
A.



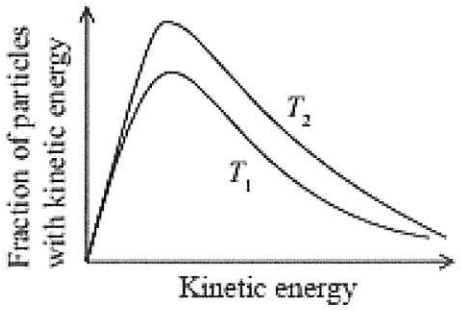
B.



C.



D.



21. Which changes increase the rate of this reaction, other conditions remaining constant?

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

I. Using larger lumps of calcium carbonate

II. Increasing the temperature of the reaction mixture

III. Increasing the concentration of hydrochloric acid

A. I and II only

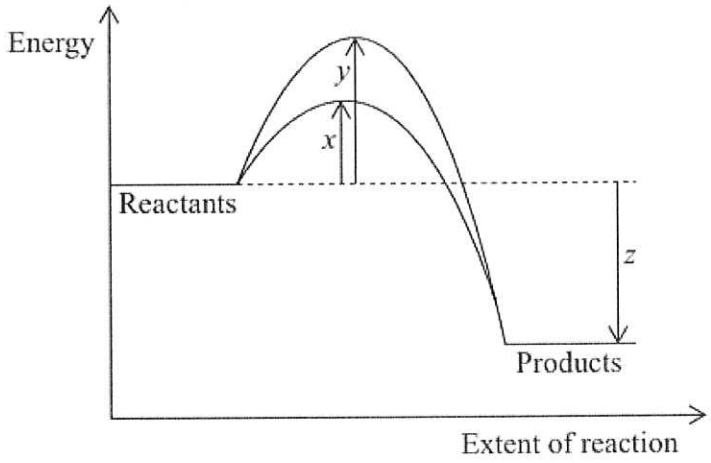
B. I and III only

C. II and III only

D. I, II and III

22.

The diagram below shows the energy changes for a reaction with and without a catalyst. Which symbols represent the activation energy, E_a, and the enthalpy change, ΔH, for the reaction with a catalyst?



	E_a (with a catalyst)	ΔH
A.	x	z
B.	y	z
C.	z	
D.	$y-x$	z

23.

Which combination of ΔH and ΔS signs will always result in a spontaneous reaction at all temperatures?

	ΔH	ΔS
A.	+	+
B.	+	−
C.	−	−
D.	−	+

24.

In an experiment to determine a specific quantity, a student calculated that her experimental uncertainty was 0.9 % and her experimental error was 3.5 %. Which statement is correct?

A. Only random uncertainties are present in this experiment.

(B.) Both random uncertainties and systematic errors are present in this experiment. ✓

C. Repeats of this experiment would reduce the systematic errors. X

D. Repeats of this experiment would reduce both systematic errors and random uncertainties. X

25.

Which would be the best method to decrease the random uncertainty of a measurement in an acid–base titration?

A. Ensure your eye is at the same height as the meniscus when reading the burette.

B. Use a different indicator for the titration.

C. Use a different burette.

(D.) Repeat the titration. ✓

(2)

Name: Jerry Jiang

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2018-2019 CHEMISTRY HL

END OF YEAR EXAM

PAPER 2

Time Allowed: 80 minutes

INSTRUCTIONS TO CANDIDATES

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- Write your answers in the boxes provided.
- Paper 2 has a maximum mark of *[50 marks]*.
- A copy of the IB Data Booklet is provided for Paper 2
- Calculators are **allowed** for Paper 2

1. Two groups of students (Group A and Group B) carried out a project* on the chemistry of some group 7 elements (the halogens) and their compounds.

(a) In the first part of the project, the two groups had a sample of iodine monochloride (a corrosive brown liquid) prepared for them by their teacher using the following reaction.

$$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$$

The following data were recorded.

Mass of $I_2(s)$	10.00 g
Mass of $Cl_2(g)$	2.24 g
Mass of ICl(l) obtained	8.60 g

(i) State the number of significant figures for the masses of $I_2(s)$ and ICl(l). *[1]*

$I_2(s)$: 4

ICl(l): 3

1

(ii) The iodine used in the reaction was in excess. Determine the theoretical yield, in g, of ICl(l). *[3]*

$n_{Cl_2} = \frac{m}{M} = \frac{2.24\,g}{70.91\,g/mol} = 0.0316\,mol$

$n_{ICl} = 2n_{Cl_2} = 0.0632\,mol$

$\therefore m_{ICl} = n \cdot M = 0.0632\,mol \cdot (162.35\,g/mol) = 10.3\,g$

3

4

(iii) Calculate the percentage yield of ICl(l). *[1]*

%Y = $\frac{8.608}{10.39} \times 100\%$ = 0.835% 83.5%

(iv) Using a digital thermometer, the students discovered that the reaction was exothermic. State the sign of the enthalpy change of the reaction, ΔH. *[1]*

– (negative)

(b) Although the molar masses of ICl and Br_2 are very similar, the boiling point of ICl is 97.4 °C and that of Br_2 is 58.8 °C. Explain the difference in these boiling points in terms of the intermolecular forces present in each liquid. *[2]*

① ICl has dipole-dipole interaction and London Dispersion Force since there's a ΔX of 0.5 between the two element and Cl is slightly negative and I is slightly positive

② Br_2 only has London Dispersion force, so it's boiling point is lower than ICl. because overall weaker IMF, overall intermolecular force is weaker.

2

(c) The students reacted $ICl(l)$ with $CsBr(s)$ to form a yellow solid, $CsICl_2(s)$, as one of the products. $CsICl_2(s)$ has been found to produce very pure $CsCl(s)$ which is used in cancer treatment.

To confirm the composition of the yellow solid, Group A determined the amount of iodine in 0.2015 g of $CsICl_2(s)$ by titrating it with 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$. The following data were recorded for the titration.

$Na_2S_2O_3$

Mass of $CsICl_2(s)$ taken (in g ± 0.0001)	0.2015
Initial burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ (in cm^3 ± 0.05)	1.05
Final burette reading of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ (in cm^3 ± 0.05)	25.25

(i) Calculate the percentage of iodine by mass in $CsICl_2(s)$, correct to **three** significant figures. *[1]*

$\%I = \frac{I}{CsICl_2} = \frac{126.908/mol}{330.715/mol} = 38.372\% = 38.4\%$

(ii) State the volume, in cm^3, of 0.0500 mol dm^{-3} $Na_2S_2O_3(aq)$ used in the titration. *[1]*

$V = 25.25 - 1.05 = 24.20\ cm^3$

2

(iii) Determine the amount, in mol, of 0.0500 mol dm^{-3} $Na_2S_2O_3$(aq) added in the titration. *[1]*

$n = V \cdot c = 0.02420\ dm^3 \cdot 0.0500\ mol \cdot dm^{-3} \cdot$

$= 0.00121\ mol$

(iv) The overall reaction taking place during the titration is:

$$CsICl_2(s) + 2Na_2S_2O_3(aq) \rightarrow NaCl(aq) + Na_2S_4O_6(aq) + CsCl(aq) + NaI(aq)$$

Calculate the amount, in mol, of iodine atoms, I, present in the sample of $CsICl_2$(s). *[1]*

$n_{Na_2S_2O_3} = 0.00121\ mol$

$n_{CsICl_2} = \frac{1}{2} n_{Na_2S_2O_3} = \frac{1}{2} \times 0.00121\ mol = 6.05 \times 10^{-4}\ mol$

$n_I = n_{CsICl_2} = 6.05 \times 10^{-4}\ mol$

(v) Calculate the mass of iodine, in g, present in the sample of $CsICl_2$(s). *[1]*

$m = n_I \times M = 6.05 \times 10^{-4}\ mol \times 126.9\ g/mol$

$= 0.0768\ g$

(vi) Determine the percentage by mass of iodine in the sample of $CsICl_2$(s), correct to **three** significant figures, using your answer from (v). *[1]*

$\%_I = \frac{0.0768\ g}{0.2015\ g} = 0.3811 = 38.1\%$

4

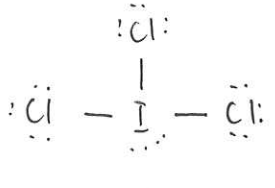
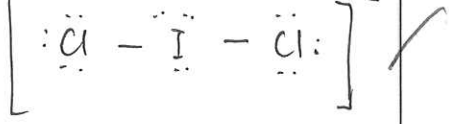
(d) Group B heated the yellow solid, $CsICl_2(s)$, which turned white and released a brown gas which condensed into a brown liquid.

Group B identified the white solid as CsCl(s). Suggest the identity of the brown liquid. *[1]*

$CsICl_2 \rightarrow CsCl + (ICl)$

...so it's likely to be ICl.

(e) When iodine reacts with excess chlorine, ICl_3 can form. Deduce the Lewis (electron dot) structure of ICl_3 and ICl_2^- and state the name of the shape of each species. *[4]*

	ICl_3	ICl_2^-
Lewis structure		
Name of shape	T-shape.	Linear.

3

2. (a) Describe the bonding that occurs in solid copper and use this to explain why copper is a good conductor of electricity and is malleable. [4]

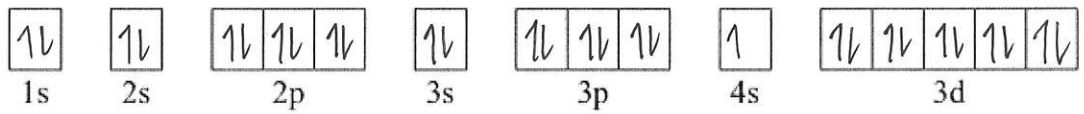
Metallic Bond: the attraction between copper cations and the lattice of delocalized sea of electrons

① conductor of electricity: filled with mobile electrons, which allows current to pass.

② malleability: the cations can easily slide pass each other while the bond is maintained, which allows the change of shape of the metal.

4

(b) Copper is a transition metal. Draw the orbital diagram (using the arrow-in-box notation) for a Cu atom. [1]



5

3.

The strength of a covalent bond is measured in terms of its bond enthalpy.

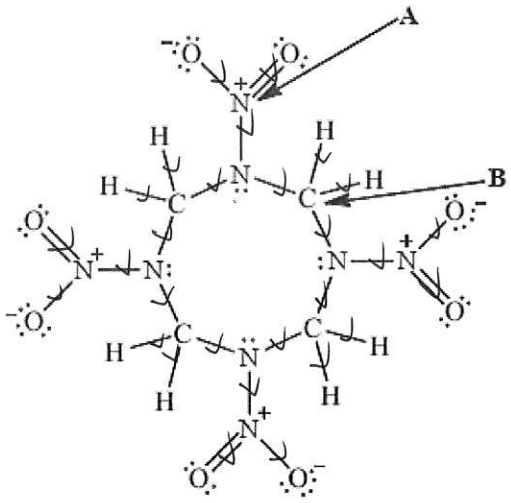
(a) Explain why the bond enthalpies given in Table 11 of the data booklets are *average* values

[2]

This is the data from the covalent bond between two atoms in different compounds, which has slightly different strength because of their surrounding. The average shows the measure of the average ~~bond~~ bond strength among all compounds.

1 in gaseous state ⇒ in gaseous state.

(b) 1,3,5,7-tetranitro-1,3,5,7-tetrazocane, shown below, can be used as an explosive.



C≡O.

1072 kJ/mol

The following equation represents the thermal decomposition of the compound.

$$C_4H_8N_8O_8(s) \rightarrow 4N_2(g) + 4CO(g) + 4H_2O(g)$$

1

(i) Calculate the molar enthalpy change of the decomposition reaction using average bond enthalpy data from Table 11 of the Data Booklet and the following additional average bond enthalpy data at 298K. N≡N C=O H-O-H. [3]

$C_4H_8N_8O_8$: C−N ×8 C−H ×8 N−O ×4 N=O ×4 N−N ×4

$4N_2+4CO+4H_2O$: O−H ×8 C≡O ×4 N≡N ×4

$\Delta H = 8\times 286 + 8\times 414 + 4\times 214 + 4\times 587 + 4\times 158 - 8\times 463 - 4\times 1072 - 4\times 945$

$= -2336\ kJ/mol$ ✓

3

(ii) Calculate the amount of heat released when 10.0g of 1,3,5,7-tetranitro-1,3,5,7-tetrazocane decomposes at 298K [2]

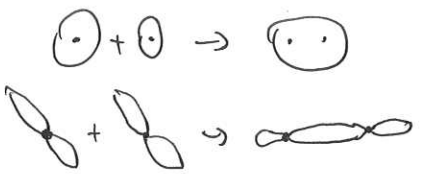
$n = \frac{m}{M} = \frac{10.0}{296.23\ g/mol} = 0.0338\ mol$

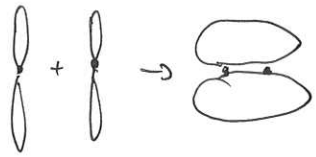
$Q = -\Delta H = -(-2336\ kJ/mol \cdot 0.0338\ mol) = 79.0\ kJ$ ✓

2

5

(iii) Describe in words and with the aid of a suitable diagram the difference between sigma (σ) and pi (π) bonds. *[3]*





overlap

sigma bonds: head-on ~~collision~~ between orbitals available for s, p, ~~the~~ ~~bond~~ every ~~bond~~ covalent bond has 1 σ each.

overlap

pi bonds: side-on ~~collision~~ between orbitals, available for p, d, ... not available for s ~~since~~ since they're spherical. single bond doesn't have π, while double has 1 and triple has 2.

3

(iv) Determine the number of σ and π bonds in 1,3,5,7-tetranitro-1,3,5,7-tetrazocane, using the Lewis structure shown on page 16. *[2]*

σ bonds: 28

π bonds: 4

2

5

(v) Explain the term *hybridization* and deduce the hybridization (sp, sp^2 or sp^3) of the atoms labelled **A** and **B** in the diagram on page 16. *[3]*

hybridization is the process of obtaining ~~molecular~~ orbitals by combining atomic orbitals.

A: sp^2

B: sp^3

~~both~~ used to make molecular orbitals, but are still on the atom.

3

(c) Methanol reacts with carbon monoxide to form ethanoic acid, $CH_3COOH(l)$.

$$CH_3OH(l) + CO(g) \rightarrow CH_3COOH(l)$$

(i) Predict the sign of the entropy change, ΔS, of the system and explain your answer. *[2]*

since there's gas in the reactant, which contains high entropy, and all product is in liquid state, entropy decreases. ΔS is negative.

2

(iii) The standard enthalpy change of formation of CO(g) is -111 kJ mol^{-1}. Using Table 12 of the Data Booklet, determine the enthalpy change of the reaction , in kJ mol^{-1}. [1]

$\Delta H_r^\circ = \Sigma \Delta H_f^\circ$ pro. $- \Sigma \Delta H_f^\circ$ rea.

$= -484 - (-111 - 239)$

$= -134$ kJ/mol

1

4

(iv) The standard entropy of CO(g) is 198 J K^{-1} mol^{-1}. Using Table 12 of the Data Booklet, determine the standard entropy change of the reaction , in J K^{-1} mol^{-1}. [1]

$\Delta S^{\ominus} = 160 \frac{J}{K \cdot mol} - 198 \frac{J}{K \cdot mol} - 127 \frac{J}{K \cdot mol} = -165\ J \cdot K^{-1} \cdot mol^{-1}$

1

(v) Determine the standard free energy change for the reaction at 298 K, in kJ mol^{-1}, using your answers from (iii) and (iv) and state whether the reaction is spontaneous or not. *[2]*

$\Delta G = \Delta H - T\Delta S$

$= -134\ kJ/mol - 298\ K \cdot (-0.165\ kJ \cdot K^{-1} \cdot mol^{-1})$

$= -84.83\ kJ/mol$

Spontaneous.

2

4. (a) [1]

Temperature and the addition of a catalyst are two factors that can affect the rate of a reaction. State **two** other factors.

① decreasing volume: ✗

② increasing reaction number (more surface area, higher concentration, higher pressure.)

1

(4)

(b)

In the reaction represented below, state **one** method that can be used to measure the rate of the reaction.

$$ClO_3^-(aq) + 5Cl^-(aq) + 6H^+(aq) \rightarrow 3Cl_2(aq) + 3H_2O(l) \qquad [1]$$

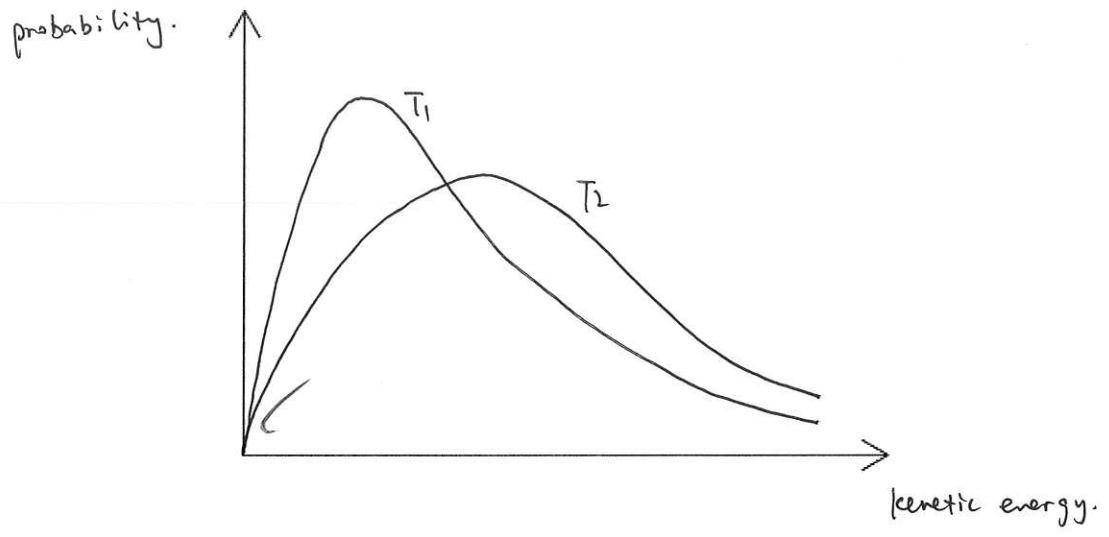
since H^+ is being consumed in the reaction, we can use a pH probe to measure the rate of change of pH, then obtain the rate of change for $[H^+]$,

$r = -\frac{1}{6}\frac{d[H^+]}{dt}$.

1

(c)

Sketch the **two** Maxwell–Boltzmann energy distribution curves for a fixed amount of gas at two different temperatures, T_1 and T_2 ($T_2 > T_1$). Label **both** axes. *[3]*



3

4