Enthalpy Test, HL Spring 2017 *[50 marks]*

You may use your calculator and the supplied tables from the Data booklet.

Multiple choice.

Circle the correct answer on your answer sheet.

1. Which compound has the highest percentage of carbon by mass? *[1 mark]*

   A. CH_4

   B. C_2H_4

   C. C_4H_{10}

   D. C_6H_6

2. Under which conditions does CH_4 have the same number of molecules as $100\ cm^3$ of O_2 at 27 °C and $1.0 \times 10^5\ Pa$? *[1 mark]*

	Volume / cm^3	Temperature / °C	Pressure / 10^5 Pa
A.	50	54	1.0
B.	50	327	1.0
C.	100	54	2.0
D.	100	327	2.0

3. Which statements are correct for silicon? *[1 mark]*

   I. Its electron arrangement is 2,8,4.

   II. It has four electrons in its highest occupied energy level.

   III. In the solid state, each silicon atom is covalently bonded to four other silicon atoms in a tetrahedral arrangement.

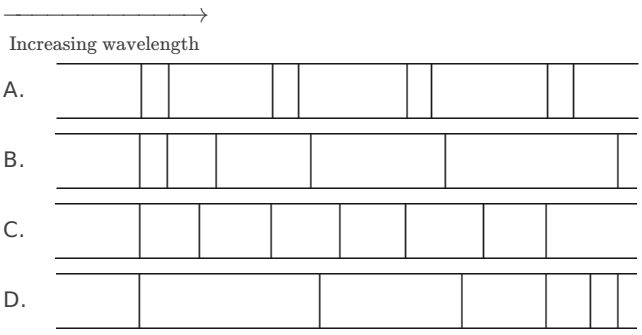
   A. I and II only

   B. I and III only

   C. II and III only

   D. I, II and III

4. Which diagram shows a pattern similar to the emission spectrum of hydrogen? *[1 mark]*



5. What is the definition of the term *first ionization energy*? *[1 mark]*

A. The energy released when one mole of electrons is removed from one mole of gaseous atoms.

B. The energy required to remove one mole of electrons from one mole of gaseous atoms.

C. The energy released when one mole of gaseous atoms gains one mole of electrons.

D. The energy required to add one mole of electrons to one mole of gaseous atoms.

6. Which statement is correct for all elements in the same period? *[1 mark]*

A. They have the same number of electrons in the highest occupied energy level.

B. They have the same chemical reactivity.

C. They have the same number of occupied energy levels.

D. They have the same number of neutrons.

7. Which compound has the highest boiling point? *[1 mark]*

A. CH_3CH_3

B. CH_3OH

C. CH_3CH_2OH

D. $CH_3CH_2CH_3$

8. Which particles are present in the lattice of a metal? *[1 mark]*

A. Negative ions

B. Positive and negative ions

C. Positive ions

D. Molecules

9. Which molecule is trigonal bipyramidal in shape? *[1 mark]*

A. PCl_3

B. $SiCl_4$

C. PCl_5

D. SF_6

10. How many σ and π bonds are present in a molecule of propyne, CH_3CCH? *[1 mark]*

	σ	π
A.	5	3
B.	6	2
C.	7	1
D.	8	0

11. The same amount of heat energy is added to 1.00 g of each substance. *[1 mark]*

Substance	Specific heat capacity / $J\,g^{-1}K^{-1}$
Copper	0.39
Aluminium	0.90
Sodium chloride	0.90
Water	4.18

Which statement is correct if all the substances are at the same temperature before the heat energy is added?

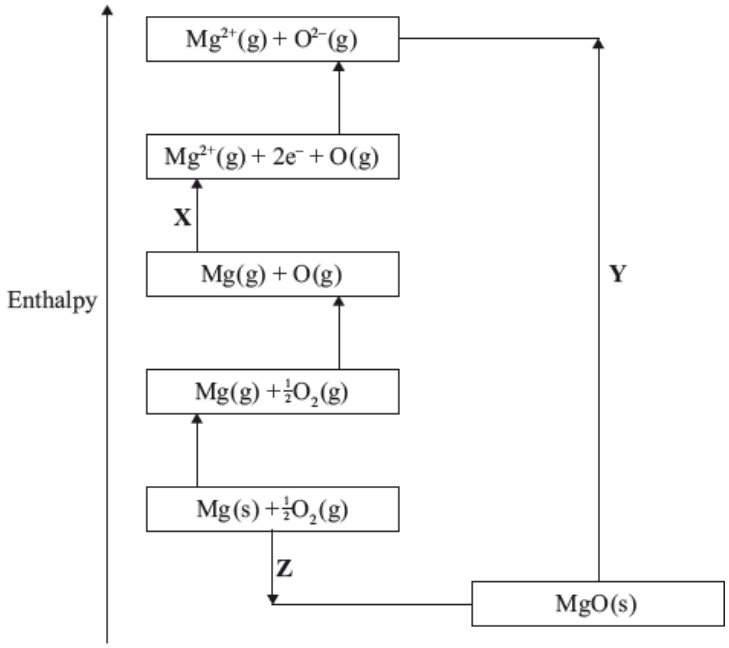
A. Copper will reach the highest temperature.

B. Water will reach the highest temperature.

C. All four substances will reach the same temperature.

D. Aluminium will reach a higher temperature than sodium chloride.

12. The Born-Haber cycle for the formation of magnesium oxide is shown below. *[1 mark]*



What is a correct description of the steps **X**, **Y** and **Z** in this cycle?

	Step X	Step Y	Step Z
A.	2nd ionization energy of Mg	enthalpy of formation of MgO	lattice enthalpy of MgO
B.	2nd ionization energy of Mg	lattice enthalpy of MgO	enthalpy of formation of MgO
C.	sum of the 1st and 2nd ionization energies of Mg	lattice enthalpy of MgO	enthalpy of formation of MgO
D.	sum of 1st and 2nd ionization energies of Mg	enthalpy of formation of MgO	lattice enthalpy of MgO

13. A 5.00 g sample of a substance was heated from 25.0 °C to 35.0 °C using 2.00×10^2 J of energy. What is the specific heat capacity of the substance in $J\,g^{-1}K^{-1}$? *[1 mark]*

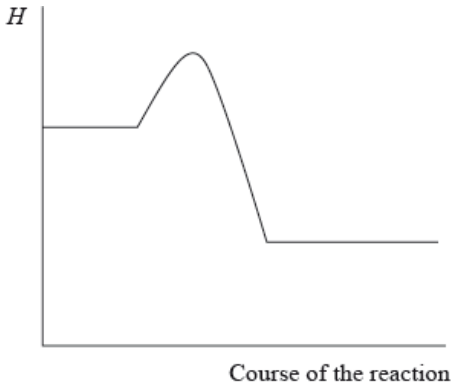
A. 4.00×10^{-3}

B. 2.50×10^{-1}

C. 2.00

D. 4.00

14. Which statement is correct given the enthalpy level diagram below? *[1 mark]*



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

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

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

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

15. Which combination of ions will give the greatest absolute lattice enthalpy? *[1 mark]*

A. A small positive ion with a high charge and a small negative ion with a high charge

B. A small positive ion with a low charge and a small negative ion with a low charge

C. A large positive ion with a high charge and a large negative ion with a high charge

D. A large positive ion with a low charge and a small negative ion with a low charge

16. What is the energy, in kJ, released when 1.00 mol of carbon monoxide is burned according to the following equation? *[1 mark]*

$$2\mathrm{CO(g)} + \mathrm{O_2(g)} \rightarrow 2\mathrm{CO_2(g)} \quad \Delta H^{\Theta} = -564\ \mathrm{kJ}$$

A. 141

B. 282

C. 564

D. 1128

17. Which is correct about energy changes during bond breaking and bond formation? *[1 mark]*

	Bond breaking	Bond formation
A.	exothermic and ΔH positive	endothermic and ΔH negative
B.	exothermic and ΔH negative	endothermic and ΔH positive
C.	endothermic and ΔH positive	exothermic and ΔH negative
D.	endothermic and ΔH negative	exothermic and ΔH positive

18. Consider the following two equations. *[1 mark]*

$2\text{Ca(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CaO(s)} \quad \Delta H^{\ominus} = +x\ \text{kJ}$

$\text{Ca(s)} + 0.5\text{O}_2\text{(g)} + \text{CO}_2\text{(g)} \rightarrow \text{CaCO}_3\text{(s)} \quad \Delta H^{\ominus} = +y\ \text{kJ}$

What is $\Delta H^{\ominus}$, in kJ, for the following reaction?

$$\text{CaO(s)} + \text{CO}_2\text{(g)} \rightarrow \text{CaCO}_3\text{(s)}$$

A. $y - 0.5x$

B. $y - x$

C. $0.5 - y$

D. $x - y$

19. In a reaction that occurs in 50 g of aqueous solution, the temperature of the reaction mixture increases by 20 °C. *[1 mark]* If 0.10 mol of the limiting reagent is consumed, what is the enthalpy change (in kJ mol^{-1}) for the reaction? Assume the specific heat capacity of the solution $= 4.2\text{kJ}^{-1}\text{K}^{-1}$.

A. $-0.10 \times 50 \times 4.2 \times 20$

B. $-0.10 \times 0.050 \times 4.2 \times 20$

C. $\frac{-50 \times 4.2 \times 20}{0.10}$

D. $\frac{-0.050 \times 4.2 \times 20}{0.10}$

20. Use the average bond enthalpies below to calculate the enthalpy change, in kJ, for the following reaction. *[1 mark]*

$$\text{H}_2\text{(g)} + \text{I}_2\text{(g)} \rightarrow 2\text{HI(g)}$$

Bond	Bond energy / kJ mol^{-1}
H–H	440
I–I	150
H–I	300

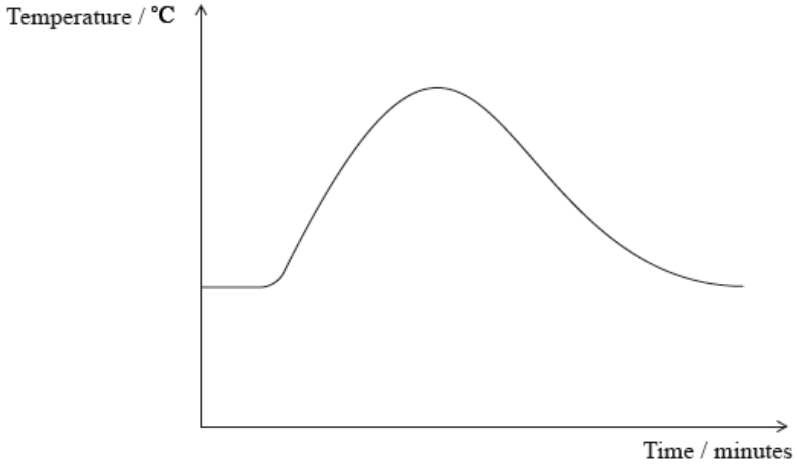
A. +290

B. +10

C. –10

D. –290

21. A student measured the temperature of a reaction mixture over time using a temperature probe. By considering the graph, which of the following deductions can be made? *[1 mark]*



I. The reaction is exothermic.

II. The products are more stable than the reactants.

III. The reactant bonds are stronger than the product bonds.

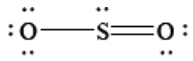
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

22. The Lewis structure of SO_2 is given below. *[1 mark]*



What is the shape of the SO_2 molecule?

A. Bent (V-shaped)

B. Linear

C. T-shaped

D. Triangular planar

23. When some solid barium hydroxide and solid ammonium thiosulfate were reacted together, the temperature of the surroundings was observed to decrease from 15 °C to –4 °C. What can be deduced from this observation? *[1 mark]*

A. The reaction is exothermic and ΔH is negative.

B. The reaction is exothermic and ΔH is positive.

C. The reaction is endothermic and ΔH is negative.

D. The reaction is endothermic and ΔH is positive.

24. The heat change in a neutralization reaction can be determined by mixing equal volumes of HCl(aq) and NaOH(aq) of the same concentration in a glass beaker. The maximum temperature change is recorded using an alcohol thermometer. *[1 mark]*

What is the biggest source of error in this experiment?

A. Heat absorbed by the glass thermometer

B. Random error in the thermometer reading

C. Heat loss to the surroundings

D. Systematic error in measuring the volumes of HCl(aq) and NaOH(aq) using burettes

Free response.

Please write all answers in the provided answer boxes. Show all work on calculation questions.

25. The standard enthalpy change of three combustion reactions is given below in kJ. *[4 marks]*

$$2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(l) \quad \Delta H^{\ominus} = -3120$$
$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) \quad \Delta H^{\ominus} = -572$$
$$C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(l) \quad \Delta H^{\ominus} = -1411$$

Based on the above information, calculate the standard change in enthalpy, $\Delta H^{\ominus}$, for the following reaction.

$$C_2H_6(g) \rightarrow C_2H_4(g) + H_2(g)$$

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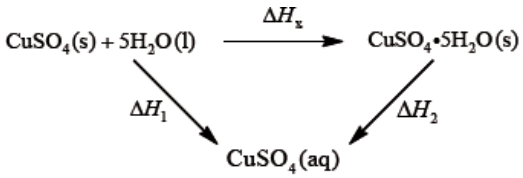
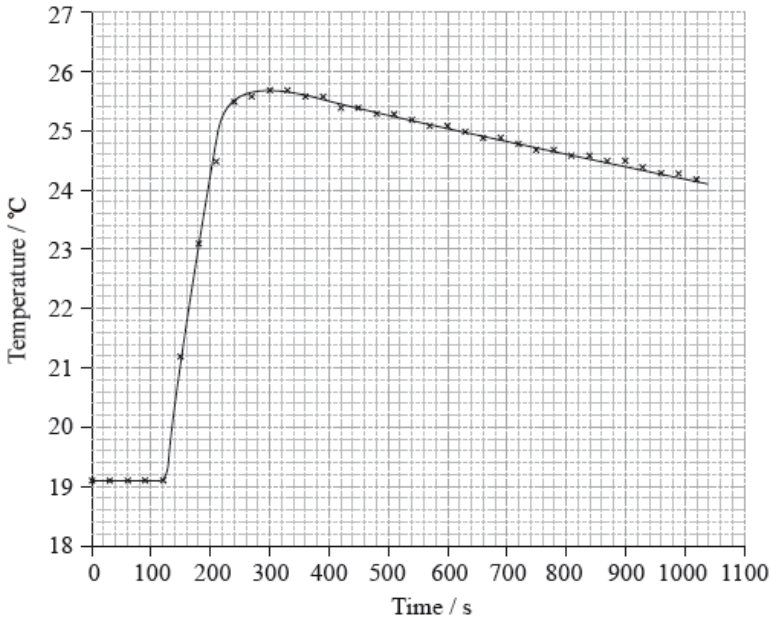
If white anhydrous copper(II) sulfate powder is left in the atmosphere it slowly absorbs water vapour giving the blue pentahydrated solid.

$$\underset{\text{(anhydrous)}}{CuSO_4(s)} + 5H_2O(l) \rightarrow \underset{\text{(pentahydrated)}}{CuSO_4 \cdot 5H_2O(s)}$$

It is difficult to measure the enthalpy change for this reaction directly. However, it is possible to measure the heat changes directly when both anhydrous and pentahydrated copper(II) sulfate are separately dissolved in water, and then use an energy cycle to determine the required enthalpy change value, ΔH_x, indirectly.



To determine ΔH_1 a student placed 50.0 g of water in a cup made of expanded polystyrene and used a data logger to measure the temperature. After two minutes she dissolved 3.99 g of anhydrous copper(II) sulfate in the water and continued to record the temperature while continuously stirring. She obtained the following results.



26a. Calculate the amount, in mol, of anhydrous copper(II) sulfate dissolved in the 50.0 g of water. *[1 mark]*

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26b. Determine what the temperature rise would have been, in °C, if no heat had been lost to the surroundings. *[2 marks]*

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26c. Calculate the heat change, in kJ, when 3.99 g of anhydrous copper(II) sulfate is dissolved in the water. *[2 marks]*

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26d. Determine the value of ΔH_1 in $\mathrm{kJ\,mol^{-1}}$. *[1 mark]*

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To determine ΔH_2, 6.24 g of pentahydrated copper(II) sulfate was dissolved in 47.75 g of water. It was observed that the temperature of the solution decreased by 1.10 °C.

26e. Calculate the amount, in mol, of water in 6.24 g of pentahydrated copper(II) sulfate. *[2 marks]*

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26f. Determine the value of ΔH_2 in $\mathrm{kJ\,mol^{-1}}$. *[2 marks]*

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26g. Using the values obtained for ΔH_1 in (a) (iv) and ΔH_2 in (b) (ii), determine the value for ΔH_x in $\mathrm{kJ\,mol^{-1}}$. *[1 mark]*

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The magnitude (the value without the + or − sign) found in a data book for ΔH_x is $78.0\ \text{kJ mol}^{-1}$.

26h. Calculate the percentage error obtained in this experiment. (If you did not obtain an answer for the experimental value of ΔH_x then use the value $70.0\ \text{kJ mol}^{-1}$, but this is **not** the true value.) *[1 mark]*

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26i. The student recorded in her qualitative data that the anhydrous copper(II) sulfate she used was pale blue rather than completely white. Suggest a reason why it might have had this pale blue colour and deduce how this would have affected the value she obtained for ΔH_x. *[2 marks]*

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27a. Define the term *average bond enthalpy*. *[2 marks]*

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27b. Deduce the balanced chemical equation for the complete combustion of butan-1-ol, $CH_3CH_2CH_2CH_2OH$. *[1 mark]*

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27c. Determine the standard enthalpy change, in $\mathrm{kJ\ mol^{-1}}$, for the complete combustion of butan-1-ol, using the information from Table 11 of the Data Booklet. *[3 marks]*

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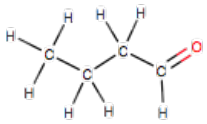
27d. Based on the types of intermolecular force present, explain why butan-1-ol, $CH_3CH_2CH_2CH_2OH$, has a higher boiling point than butanal, $CH_3CH_2CH_2CHO$.  (butanal) *[2 marks]*

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