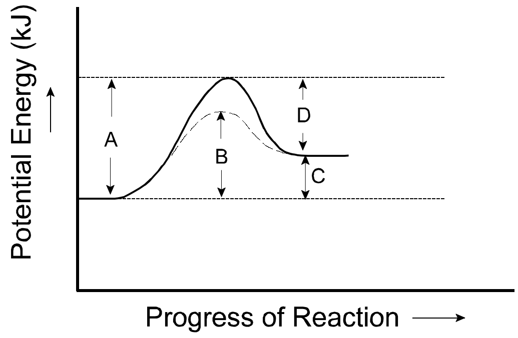
PART I
Total Value: 50%

Instructions: Shade the letter of the correct answer on the computer scorable answer sheet provided.

1. In the potential energy diagram below, which represents the activation energy for the reverse reaction?



(A) A
(B) B
(C) C
✔(D) D

2. Carbon monoxide, CO(g), reacts with nitrogen dioxide, $NO_2(g)$ according to the reaction below. Which describes the reaction if $E_{a\ (forward)} = 134$ kJ?

$$CO(g) + NO_2(g) \rightarrow CO_2(g) + NO(g) + 226\ kJ$$

	$E_{a\ (reverse)}$	Reaction type
(A)	92	endothermic
(B)	92	exothermic
(C)	360	endothermic
✔(D)	360	exothermic

3. Which reaction could have produced the data below?

Time (min)	pH
0.0	1.301
1.0	1.398
2.0	1.523
3.0	1.699
4.0	2.000

(A) $Cl_2(g) + H_2(g) \rightarrow 2\ HCl(g)$
(B) $Cl_2(g) + 2\ KI(aq) \rightarrow 2\ KCl(aq) + I_2(s)$
✔(C) $2\ HCl(aq) + Mg(s) \rightarrow MgCl_2(aq) + H_2(g)$
(D) $H_2O(\ell) + SO_3(g) \rightarrow H_2SO_4(aq)$

4. What effect does a catalyst have on a reaction?

(A) changes ΔH of the reaction
✔(B) decreases the activation energy
(C) decreases the potential energy of the products
(D) increases the kinetic energy of the reactants

5. Under standard conditions, which reacts most rapidly with oxygen gas?

✔(A) $CH_4(g)$
(B) $C_3H_8(g)$
(C) $C_{10}H_{22}(\ell)$
(D) $C_{25}H_{52}(s)$

6. For the reactions below, what is the reaction intermediate?

Step 1: $O_3(g) + NO(g) \rightarrow NO_2(g) + O_2(g)$

Step 2: $NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$

(A) NO
✔(B) NO_2
(C) O
(D) O_2

7. In which reaction will increasing the volume of the reaction vessel cause a shift in the equilibrium to favour the products?

✔(A) $2\,CO_2(g) \rightleftharpoons 2\,CO(g) + O_2(g)$
(B) $2\,HI(g) \rightleftharpoons H_2(g) + I_2(g)$
(C) $2\,NO(g) + 2\,H_2(g) \rightleftharpoons N_2(g) + 2\,H_2O(g)$
(D) $2\,NO_2(g) \rightleftharpoons N_2O_4(g)$

8. Which change in the equilibrium below will result in the highest concentration of $SO_2(g)$?

$$S_8(s) + 8\,O_2(g) \rightleftharpoons 8\,SO_2(g) + \text{heat}$$

(A) add catalyst
✔(B) decrease temperature
(C) increase pressure
(D) remove $O_2(g)$

9. Which is **not** included in an equilibrium expression?

(A) $CO_2(g)$
(B) $Fe^{2+}(aq)$
(C) HCl(aq)
✔(D) Zn(s)

10. Which corresponds to an equilibrium in which the products are favoured?

(A) $K = 0$
(B) $K = 1 \times 10^{-5}$
(C) $K = 1$
✔(D) $K = 1 \times 10^{5}$

11. What is the equilibrium constant, K, for the reaction below given the equilibrium concentrations: $H_2CO_3 = 3.3 \times 10^{-2}$ mol/L, $HCO_3^- = 1.2 \times 10^{-4}$ mol/L, $H_3O^+ = 1.2 \times 10^{-4}$ mol/L?

$$H_2CO_3(aq) + H_2O(\ell) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

✔(A) 4.4×10^{-7}
(B) 3.6×10^{-3}
(C) 2.8×10^{2}
(D) 2.3×10^{6}

12. What is the equilibrium concentration of $I_2(g)$ when the concentration of I(g) is 0.00100 mol/L?

$$I_2(g) \rightleftharpoons 2\,I(g) \qquad K = 3.8 \times 10^{-5}$$

✔(A) 0.026 mol/L
(B) 0.038 mol/L
(C) 26 mol/L
(D) 38 mol/L

13. Which operationally defines a potassium hydroxide solution?

✔(A) feels slippery
(B) pH = 2.0
(C) tastes sour
(D) turns litmus red

14. According to Arrhenius theory, which substance is a base?

(A) $Ca_3(PO_4)_2$
(B) CH_3OH
✔(C) KOH
(D) Na_2CO_3

15. Which properties best describe a 0.10 mol/L solution with the highest pH?

	Reaction with active metal	Electrical conductivity	Litmus
(A)	moderate	moderate	red
✔(B)	none	high	blue
(C)	none	moderate	blue
(D)	vigorous	high	red

16. Which describes an amphoteric substance?

(A) can only accept a proton
(B) can only accept an electron
✔(C) can accept or donate a proton
(D) can accept or donate an electron

17. Which describes the percent dissociation of a strong base?

(A) 25 %
(B) 50 %
(C) 75 %
✔(D) 100 %

18. Which is the strongest base?

✔(A) HBO_3^{2-}
(B) HSO_4^-
(C) PO_4^{3-}
(D) SO_4^{2-}

19. What is the net ionic equation for the reaction between HF(aq) and Na_2CO_3(aq)?

(A) $2\ H^+(aq) + 2\ F^-(aq) + Na_2CO_3(aq) \rightleftharpoons H_2CO_3(aq) + 2\ NaF(aq)$
✔(B) $2\ HF(aq) + CO_3^{2-}(aq) \rightleftharpoons H_2CO_3(aq) + 2\ F^-(aq)$
(C) $2\ HF(aq) + 2\ Na^+(aq) \rightleftharpoons 2\ H^+(aq) + 2\ Na^+(aq) + 2\ F^-(aq)$
(D) $2\ HF(aq) + Na_2CO_3(aq) \rightleftharpoons H_2CO_3(aq) + 2\ NaF(aq)$

20. What is the pH for a solution with a hydronium ion concentration of 1.25×10^{-4}?

(A) −10.097
(B) −3.903
✔(C) 3.903
(D) 10.097

21. What is the pOH for a 0.110 mol/L strong acid solution?

(A) 0.110
(B) 0.959
✔(C) 13.041
(D) 13.890

22. What is $[OH^-]$ for a solution with pH = 12.25?

(A) 5.6×10^{-13} mol/L
✔(B) 1.8×10^{-2} mol/L
(C) 1.7 mol/L
(D) 65 mol/L

23. Which K_a value represents a solution with the lowest pOH?

✔(A) 1.7×10^{-9}
(B) 1.6×10^{-6}
(C) 1.9×10^{-5}
(D) 1.1×10^{-2}

24. Given below is an incomplete K_a or K_b expression. Which species, X, would give a correct expression?

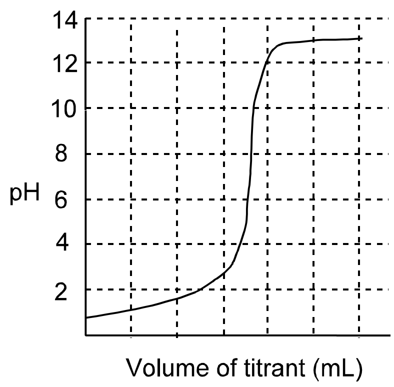
$$\frac{[X][HSO_3^-]}{[H_2SO_3]}$$

(A) H_2O
✔(B) H_3O^+
(C) OH^-
(D) SO_3^{2-}

25. Which is the best example of a buffer solution?

(A) $CH_3COOH(aq)$ and $NH_3(aq)$
(B) $HBr(aq)$ and $Br^-(aq)$
✔(C) $HPO_4^{2-}(aq)$ and $PO_4^{3-}(aq)$
(D) $KOH(aq)$ and $OH^-(aq)$

26. Which is the best indicator for the titration curve below?



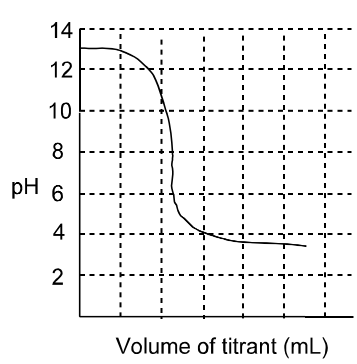
(A) indigo carmine
(B) methyl orange
✔(C) phenol red
(D) thymolphthalein

27. A flask containing an unknown solution of concentration 0.100 mol/L, is tested with three indicators. Based on the data below, what is the pH of this solution?

Indicator	Colour
chlorophenol red	red
phenolphthalein	colourless
bromothymol blue	green

(A) 5.8
(B) 6.0
✔(C) 7.0
(D) 7.6

28. Which best describes the sample that is titrated to give the titration curve below?



(A) strong acid
✔(B) strong base
(C) weak acid
(D) weak base

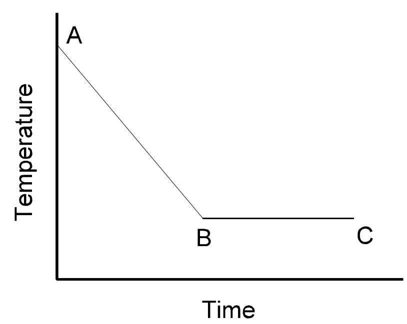
29. Which describes the process and the ΔH when heat is released from a system to its surroundings?

	Process	ΔH
(A)	endothermic	negative
(B)	endothermic	positive
✔(C)	exothermic	negative
(D)	exothermic	positive

30. What mass of water will increase its temperature from 20.0 °C to 80.0 °C when 31 kJ of heat is applied?

(A) 0.12 g
(B) 94 g
✔(C) 120 g
(D) 7800 g

31. In the diagram below, which describes the energy change from A to B?



✔(A) kinetic energy is decreasing
(B) kinetic energy is increasing
(C) potential energy is decreasing
(D) potential energy is increasing

32. Which is the correct unit for heat capacity?

(A) J
(B) J/g
✔(C) J/°C
(D) J/g·°C

33. Which equation represents the standard formation of sodium hydrogen carbonate, $NaHCO_3$?

✔(A) $Na(s) + \frac{1}{2} H_2(g) + C(s) + \frac{3}{2} O_2(g) \rightarrow NaHCO_3(s)$

(B) $NaHCO_3(s) \rightarrow Na(s) + \frac{1}{2} H_2(g) + C(s) + \frac{3}{2} O_2(g)$

(C) $Na^+(aq) + HCO_3^-(aq) \rightarrow NaHCO_3(s)$

(D) $NaHCO_3(s) \rightarrow Na^+(aq) + HCO_3^-(aq)$

34. What mass of argon condenses if there is an energy change of 8.00 kJ? (ΔH_{vap} for argon is 6.30 kJ/mol)

(A) 0.0318 g
(B) 1.27 g
(C) 31.5 g
✔(D) 50.7 g

35. Which is best measured using a bomb calorimeter?

✔(A) ΔH_{comb}
(B) ΔH_{fus}
(C) ΔH_{soln}
(D) ΔH_{neut}

36. The equation below shows the enthalpy change that occurs when calcium chloride dissolves in water. Which describes this process?

$$CaCl_2(s) \rightarrow Ca^{2+}(aq) + 2\ Cl^-(aq) + 82.8\ kJ$$

	ΔH_{soln} (kJ/mol)	Water temperature
(A)	−82.8	decreases
✔(B)	−82.8	increases
(C)	82.8	decreases
(D)	82.8	increases

37. Which is the most likely ΔH for a nuclear change?

(A) 10^{-6} kJ/mol
(B) 10^{-3} kJ/mol
(C) 10^{3} kJ/mol
✔(D) 10^{9} kJ/mol

38. How much energy is contained in a 50.0 g cereal bar if its fuel value is 0.0134 kJ/g?

(A) 2.68×10^{-4} kJ
(B) 1.34×10^{-2} kJ
✔(C) 6.70×10^{-1} kJ
(D) 3.73×10^{3} kJ

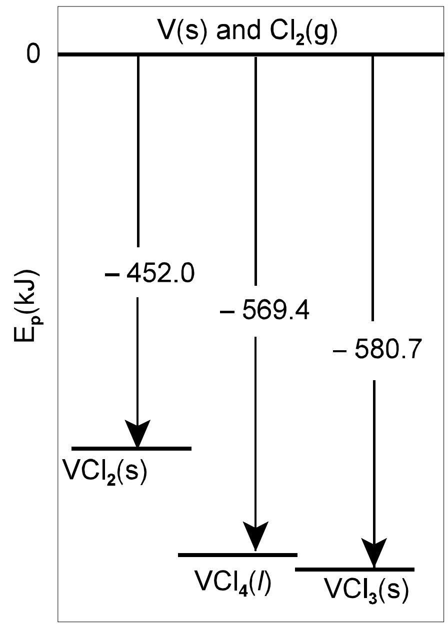
39. What is the enthalpy change for the reaction below?

$$C_2H_4(g) + H_2O(\ell) \rightarrow C_2H_5OH(\ell)$$

Compound	$\Delta H°_f$ (kJ/mol)
$C_2H_4(g)$	52.4
$H_2O(\ell)$	−285.8
$C_2H_5OH(\ell)$	−277.6

(A) −511 kJ
✔(B) −44.2 kJ
(C) 44.2 kJ
(D) 511 kJ

40. The diagram shown illustrates the formation enthalpies of V(s), $Cl_2(g)$ and some of their compounds. What is the energy change when 1.00 mol of $VCl_4(\ell)$ decomposes to form $VCl_2(s)$ and $Cl_2(g)$?



(A) −117 kJ
(B) −71.3 kJ
(C) 71.3 kJ
✔(D) 117 kJ

41. Which describes oxidation?

(A) gain of electrons
(B) gain of protons
✔(C) loss of electrons
(D) loss of protons

42. What is the oxidation number of O in $O_2(g)$?

(A) −2
✔(B) 0
(C) +1
(D) +2

43. Which species is reduced in the reaction below?

$$Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$$

(A) Zn(s)
(B) $Zn^{2+}(aq)$
(C) Cu(s)
✔(D) $Cu^{2+}(aq)$

44. What does the salt bridge maintain in an electrochemical cell?

(A) constant pH
(B) constant temperature
✔(C) electrical neutrality
(D) initial concentration of ions

45. What is the order for electrochemical cell notation?

✔(A) anode|anode ion solution||cathode ion solution|cathode
(B) anode ion solution|anode||cathode ion solution|cathode
(C) cathode|cathode ion solution|| anode|anode ion solution
(D) cathode ion solution|cathode|| anode|anode ion solution

46. What is the oxidation half-reaction for the electrochemical cell below?

$$Ni|Ni^{2+}||Cd^{2+}|Cd$$

(A) $Cd \rightarrow Cd^{2+} + 2\,e^-$
(B) $Cd^{2+} + 2\,e^- \rightarrow Cd$
✔(C) $Ni \rightarrow Ni^{2+} + 2\,e^-$
(D) $Ni^{2+} + 2\,e^- \rightarrow Ni$

47. What is the cell voltage, E°, for the electrochemical cell formed from the half-reactions below?

$$Fe^{2+}(aq) + 2\,e^- \rightarrow Fe(s)$$
$$Hg^{2+}(aq) + 2\,e^- \rightarrow Hg(\ell)$$

(A) −1.30 V
(B) −0.40 V
(C) +0.40 V
✔(D) +1.30 V

48. Which would balance the reaction below?

$$X^- \rightarrow X^{2-}$$

(A) add one electron to the product side
✔(B) add one electron to the reactant side
(C) add two electrons to the product side
(D) add two electrons to the reactant side

49. Which describes the reaction below?

$$Ni(s) + Pb^{2+}(aq) \rightarrow Ni^{2+}(aq) + Pb(s)$$

	E°(V)	Spontaneity
(A)	−0.13	non-spontaneous
(B)	−0.13	spontaneous
(C)	0.13	non-spontaneous
✔(D)	0.13	spontaneous

50. A copper spoon was electroplated with silver. Which reaction occurred at the cathode during electroplating?

(A) $Ag \rightarrow Ag^+ + e^-$
✔(B) $Ag^+ + e^- \rightarrow Ag$
(C) $Cu \rightarrow Cu^{2+} + 2\,e^-$
(D) $Cu^{2+} + 2\,e^- \rightarrow Cu$

PART II
Total Value: 50%

Instructions: Complete all items in this section. Your responses should be clearly presented in a well-organized manner with proper use of units, formulae and significant figures where appropriate.

Value

2% 51.(a) Explain the effect on reaction rate if the concentration of CO(g) is increased in the reaction below.

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 3\ CO_2(g) + 2\ Fe(s) + 24.8\ kJ$$

Reaction Rate will increase. [1 mark]

- more reacting particles [½ mark] result in more collisions with proper orientation and sufficient energy [½ mark] resulting in an increased rate

3% (b) Consider the reaction mechanism below.

Step	Reaction Mechanism	Rate
1	$I_2 \rightarrow 2\ I$	very fast
2	$I + H_2 \rightarrow H_2I$	fast
3	$H_2I + I \rightarrow 2\ HI$	slow

i) Write the equation for the overall reaction.

$$\mathbf{I_2 + H_2 \rightarrow 2\ HI}$$ **[1 mark]**

ii) Explain why increasing the concentration of I_2 will have little effect on the overall reaction rate.

The rate determining step (RDS) determines the overall reaction rate; ie: the slowest step. [1 mark]

I_2 is not in the RDS. [1 mark]

Value

2% 51.(c) Smog consists of many different gases including N_2O_4 which is colourless and NO_2 which is brown. Using the equilibrium below, explain why some people believe that smog is **not** a problem in winter.

$$N_2O_4(g) + 59\text{ kJ} \rightleftharpoons 2\ NO_2(g)$$

colourless *brown*

Winter means the temperature decreases. LCP predicts the system will try to increase the temperature by shifting left to produce energy. [1 mark]

A shift left causes the air to become less brown or even colourless. Since smog cannot be seen, it is believed not to be a problem. [1 mark]

4% (d) 4.00 mol of $H_2S(g)$ is placed in a 2.00 L flask at 1400 °C. When the equilibrium below is reached, 6.00% of the $H_2S(g)$ has reacted. Calculate the value of the equilibrium constant.

	$2\ H_2S\ (g)$	$\rightleftharpoons$	$2\ H_2(g)$	$+\ S_2(g)$	
I	$\frac{4.00\text{ mol}}{2.00\text{ L}} = 2.00\text{ mol/L}$		**0**	**0**	
C	$-2x$		$+2x$	$+x$	
E	$2.00 - 2x$		$2x$	x	**(½ mark)**

$[H_2S]_c = 2.00\text{ mol/L} \times 0.0600 = 0.120\text{ mol/L} = 2x$ (½ mark)

thus $x = 0.120 / 2 = 0.0600\text{ mol/L}$ (½ mark)

$[H_2]_{eq} = 2x = 2(0.0600) = 0.120\text{ mol/L}$ (½ mark)

$[S_2]_{eq} = x = 0.0600\text{ mol/L}$ (½ mark)

$[H_2S]_{eq} = 2.00\text{ mol/L} - 2x = 2.00 - 2(0.0600) = 1.88\text{ mol/L}$ (½ mark)

$$K = \frac{[H_2]^2[S_2]}{[H_2S]^2} = \frac{(0.120)^2(0.0600)}{(1.88)^2} = 2.44 \times 10^{-4}$$

(½ mark) (½ mark)

Value

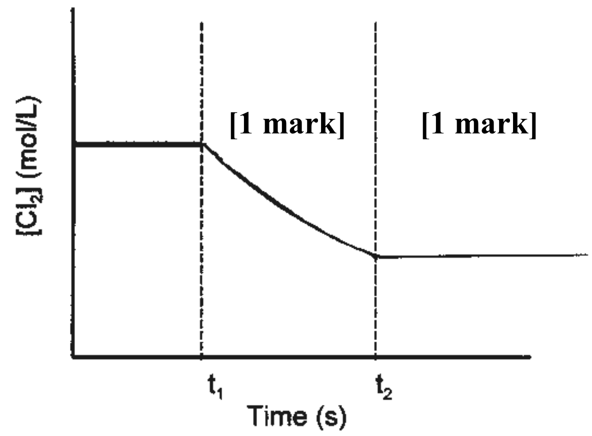
2% 51.(e) The system below is allowed to reach equilibrium at 400 °C.

$$4\,HCl(g) + O_2(g) \rightleftharpoons 2\,H_2O(g) + 2\,Cl_2(g) \qquad \Delta H = -114\text{ kJ}$$

The equilibrium concentration of Cl_2 is graphed below.

- At t_1 the reaction vessel is heated and the reaction is allowed to re-establish equilibrium.
- At t_2 a catalyst is added.

For each change, extend the line to indicate the effect on $[Cl_2]$.



2% 52.(a) Determine the Brønsted-Lowry acid-base neutralization reaction that occurs between $NaHSO_4(aq)$ and $K_2CO_3(aq)$.

Species:	Na^+	HSO_4^-	K^+	CO_3^{2-}	H_2O
	neutral	A/B	neutral	B	A/B
		SA		SB	

$$\mathbf{HSO_4^- + CO_3^{2-} \rightleftharpoons HCO_3^- + SO_4^{2-}}$$

(½ mark) (½ mark) (½ mark) (½ mark)

4% (b) Calculate the pH of a 2.97 mol/L $F^-(aq)$ solution given $K_b = 1.15 \times 10^{-11}$.

	F^-	$+ H_2O \rightleftharpoons$	OH^-	$+$ HF	
I	**2.97**		**0**	**0**	
C	**$-x$**		**$+x$**	**$+x$**	
E	**$2.97 - x$**		**$+x$**	**$+x$**	**(½ mark)**

check $\dfrac{[F^-]_i}{K_b} = \dfrac{2.97}{1.15 \times 10^{-11}} > 500$ **thus assume** $2.97 - x \sim 2.97$

(½ mark) (½ mark)

$K_b = \dfrac{[HF]\,[OH^-]}{[F^-]}$ **(½ mark)**

$1.15 \times 10^{-11} = \dfrac{x^2}{2.97}$ **(½ mark)**

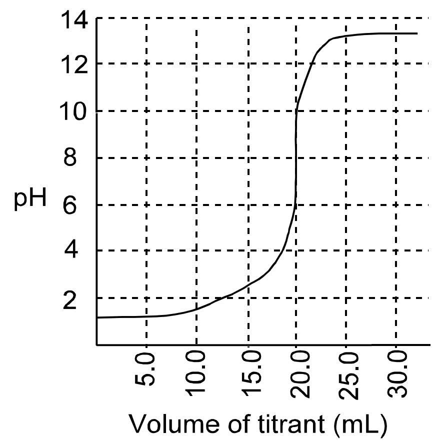
$x = 5.84(4) \times 10^{-6} = [OH^-]$ **(½ mark)**

pOH = - log [OH⁻] = - log 5.84(4) x 10⁻⁶ = 5.233 **(½ mark)**

pH = 14.000 - pOH = 14.000 - 5.233 = 8.767 **(½ mark)**

Value

4% 52.(c) A titration experiment was performed by adding 0.120 mol/L NaOH(aq) solution to 30.0 mL of an unknown monoprotic acid solution. Given the titration curve below, determine the concentration of the unknown acid.



From the graph, the volume of NaOH added at the equivalence point is 20.0 mL. **[½ mark]**

$$\mathbf{NaOH + HX \rightarrow NaX + HOH}$$ **[½ mark]**

$\mathbf{n_{NaOH} = c \times v = (0.120\ mol/L)(0.0200\ L) = 0.00240\ mol}$ **[½ mark]**

$\mathbf{n_{HX} = 0.00240\ mol\ NaOH \times \dfrac{1\ mol\ HX}{1\ mol\ NaOH} = 0.00240\ mol}$ **[½ mark]**

$\mathbf{c_{HX} = \dfrac{n}{v} = \dfrac{0.00240\ mol}{0.0300\ L} = 0.0800\ mol/L}$ **[½ mark]**

Science Communication	**½ mark units** **½ mark significant figures**

4% (d) If a 0.250 mol/L solution of a weak acid, HA, has a pH of 1.415, determine the acid.

	$\mathbf{HA}$	+	$\mathbf{H_2O}$	$\rightleftharpoons$	$\mathbf{H_3O^+}$	+	$\mathbf{A^-}$	
I	**0.250**				**0**		**0**	
C	$-x$				$+x$		$+x$	
E	$0.250 - x$				$+x$		$+x$	**(½ mark)**

$\mathbf{[H_3O^+] = 10^{-pH} = 10^{-1.415} = 0.0384(6)\ mol/L} = x$ **(1 mark)**

$\mathbf{[A^-]} = x = \mathbf{0.0384(6)\ mol/L}$ **(½ mark)**

$\mathbf{[HA] = 0.250} - x = \mathbf{0.250 - 0.0384(6) = 0.211(5)\ mol/L}$ **(½ mark)**

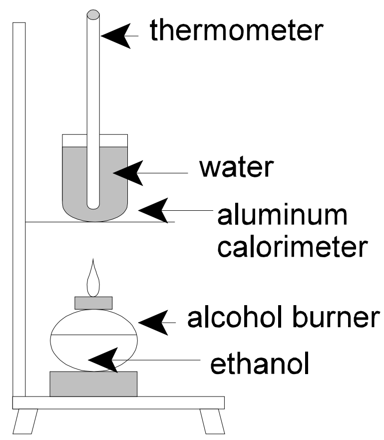
$\mathbf{K_a = \dfrac{[H_3O^+][A^-]}{[HA]} = \dfrac{[0.0384(6)]^2}{0.211(5)} = 6.99 \times 10^{-3}}$ **(½ mark)**

The acid is $\mathbf{H_3PO_4}$. **(1 mark)**

Value

5%   53.(a) A student assembled the following apparatus to determine the molar enthalpy of combustion for ethanol, $C_2H_5OH(\ell)$ and the results below were recorded. If all of the heat produced from the ethanol is absorbed by the water and the aluminum calorimeter, calculate the molar enthalpy of combustion for ethanol.

mass of H_2O	500.0 g
mass of aluminum calorimeter	42.21 g
mass of ethanol burned	6.13 g
initial temperature of water and aluminum	25.0 °C
final temperature of water and aluminum	91.0 °C
$c_{aluminum}$	0.900 J/g·°C
c_{water}	4.184 J/g·°C



$q_{lost} = - q_{gain}$ **$\Delta T = 91.0°C - 25.0°C = 66.0°C$**

$q\,(C_2H_5OH) = - [\, (mc\Delta T)_{H2O} + (mc\Delta T)_{Al} \,]$
$= - [\, (500.0\text{ g} \times 4.184\text{ J/g•°C} \times 66.0°C) + (42.21\text{ g} \times 0.900\text{ J/g•°C} \times 66.0°C)$
$= - [\, 138(072)\text{ J} + 250(7)\text{ J} \,]$ **(2 marks)**
$= - 140(579)\text{ J}$
$= - 141\text{ kJ}$ **(1 mark)**

$\Delta H_{comb}\,(C_2H_5OH) = \dfrac{q}{n} = \dfrac{-140,(579)\text{ kJ}}{(6.13\text{ g} / 46.08\text{ g/mol})} = \dfrac{-140,(579)\text{ kJ}}{0.133\text{ mol}} = -105(7)\text{ kJ/mol}$

$= -1.06 \times 10^3\text{ kJ/mol}$
(1 mark)

Science Communication	**½ mark units** **½ mark significant figures**

Value

4% 53.(b) Using the data determine ΔH for the reaction below.

$$2\,LiH(s) + O_2(g) \rightarrow Li_2O(s) + H_2O(\ell)$$

x 1	$2\,LiOH(s)$	$\rightarrow$	$Li_2O(s) + H_2O(\ell)$	$\Delta H = +379.1$ kJ
x -2	$LiOH(s) + H_2(g)$	$\rightarrow$	$LiH(s) + H_2O(\ell)$	$\Delta H = +111.0$ kJ
x 1	$2\,H_2(g) + O_2(g)$	$\rightarrow$	$2\,H_2O(\ell)$	$\Delta H = -285.9$ kJ

$$\mathbf{2\,LiOH(s) \rightarrow Li_2O(s) + H_2O(\ell) \qquad \Delta H = +379.1\text{ kJ}}$$

$$\mathbf{2\,LiH(s) + 2\,H_2O(\ell) \rightarrow 2\,LiOH(s) + 2\,H_2(g) \qquad \Delta H = -\ 222.0\text{ kJ}}$$

$$\mathbf{2\,H_2(g) + O_2(g) \rightarrow 2\,H_2O(\ell) \qquad \Delta H = -\ 285.9\text{ kJ}}$$

$$\mathbf{2\,LiH(s) + O_2(g) \rightarrow Li_2O(s) + H_2O(\ell) \qquad \Delta H = -\ 128.8\text{ kJ}}$$

4% (c) The fuel value of methane is 55.48 kJ/g. Using the data below, calculate the energy required to break the C – H bond.

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

Bond	Bond Energy (kJ/mol)
H – O	460
C = O	745
O = O	498

ΔH = 55.48 kJ/g x 16.05 g/mol) = 890.4(5) kJ/mol **(1 mark)**

since ΔH_{comb} = - 890.4(5) kJ/mol (combustion is exo) **(½ mark sign)**

4 x (C - H) + 2x (O = O) → 2 x (C = O) + 4 x (O - H)

$\Delta H = \Sigma\, BE_{reactants} - \Sigma\, BE_{products}$

- 890.4(5) kJ = [(4 x C-H) + (2 x 498)] - [(2 x 745) + (4 x 460)]

- 890.4(5) kJ = [(4 x C-H) + 996] - [1490 + 1840] **(1 ½ marks)**

- 890.4(5) kJ = (4 x C-H) + 996 - 3330 kJ

4 x C-H = - 890.4(5) kJ - 996 kJ + 3330 kJ

4 x C-H = 1443.(55) kJ

C-H = 361 kJ/mol **(1 mark)**

Value

3%   54.(a) Balance the reaction below under acidic conditions.

$$N_2H_4 + MnO_4^- \rightarrow N_2 + Mn^{2+}$$

$\mathbf{N_2H_4 \rightarrow N_2 + 4\,H^+ + 4\,e^-\quad]\times 5}$ **(½ mark)**

$\mathbf{5\,e^- + 8\,H^+ + MnO_4^- \rightarrow Mn^{2+} + 4\,H_2O\quad]\times 4}$ **(½ mark)**

$\mathbf{5\,N_2H_4 \rightarrow 5\,N_2 + 20\,H^+ + 20\,e^-}$ **(½ mark)**

$\mathbf{20\,e^- + 32\,H^+ + 4\,MnO_4^- \rightarrow 4\,Mn^{2+} + 16\,H_2O}$ **(½ mark)**

$\mathbf{5\,N_2H_4 + 12\,H^+ + 4\,MnO_4^- \rightarrow 5\,N_2 + 4\,Mn^{2+} + 16\,H_2O}$ **(1 mark)**

4%   (b) $E°_{cell}$ for the cell below is +2.12 V.

$$La|La^{3+}||Cd^{2+}|Cd$$

i) Write the balanced overall cell reaction.

$\mathbf{La \rightarrow La^{3+} + 3\,e^-\quad]\times 2}$ **(½ mark)**

$\mathbf{Cd^{2+} + 2\,e^- \rightarrow Cd\quad]\times 3}$ **(½ mark)**

$\mathbf{2\,La + 3\,Cd^{2+} \rightarrow 2\,La^{3+} + 3\,Cd}$ **(1 mark)**

ii) Calculate the standard reduction potential for the $La|La^{3+}$ half-cell.

$\mathbf{La \rightarrow La^{3+} + 3\,e^-\qquad \xi = ?}$

$\mathbf{Cd^{2+} + 2\,e^- \rightarrow Cd\qquad \xi = -0.40\ V}$

$\mathbf{\xi_{cell} = 2.12\ V}$

$\mathbf{\xi_{oxidation} = 2.12\ V - (-0.40\ V) = 2.52\ V}$ **(½ mark)**

thus $\mathbf{\xi_{reduction} = -2.52\ V}$ **(½ mark)**

Science Communication	**½ mark units** **½ mark significant figures**

Value

3% 54.(c) Given the half-reactions below, determine if a manganate ion, MnO_4^{2-}, can exist in an acidic solution under standard conditions.

x 2] $MnO_4^{2-} \rightarrow MnO_4^{-} + e^{-}$ $E° = -0.56$ V

x -1] $MnO_2 + 2\,H_2O \rightarrow MnO_4^{2-} + 4\,H^{+} + 2\,e^{-}$ $E° = -2.27$ V

$2\,MnO_4^{2-} \rightarrow 2\,MnO_4^{-} + 2\,e^{-}$ $E° = -0.56$ V (½ mark)

$MnO_4^{2-} + 4\,H^{+} + 2\,e^{-} \rightarrow MnO_2 + 2\,H_2O$ $E° = +2.27$ V (½ mark)

$3\,MnO_4^{2-} + 4\,H^{+} \rightarrow 2\,MnO_4^{-} + MnO_2 + 2\,H_2O$ $E° = +1.71$ V (1 mark)

Under standard acidic conditions, MnO_4^{2-} would react spontaneously, thus it would not exist. (1 mark)