UNIVERSITI SAINS MALAYSIA

Final Examination
2015/2016 Academic Session

May/June 2016

JIK 223 – Physical Chemistry I
[Kimia Fizik I]

Duration : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **TEN** printed pages before you begin the examination.

Answer **FIVE** questions. Answer the questions in English. You may also answer the questions in Bahasa Malaysia, but not a mix of both languages.

All answers must be written in the answer booklet provided.

Each question is worth 20 marks and the mark for each sub question is given at the end of that question.

In the event of any discrepancies in the exam questions, the English version shall be used.

*Sila pastikan bahawa kertas peperiksaan ini mengandungi **SEPULUH** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.*

*Jawab **LIMA** soalan. Jawab soalan-soalan dalam Bahasa Inggeris. Anda juga dibenarkan menjawab soalan dalam Bahasa Malaysia, tetapi campuran antara kedua-dua bahasa ini tidak dibenarkan.*

Setiap jawapan mesti dijawab di dalam buku jawapan yang disediakan.

Setiap soalan bernilai 20 markah dan markah subsoalan diperlihatkan di penghujung subsoalan itu.

Sekiranya terdapat sebarang percanggahan pada soalan peperiksaan, versi Bahasa Inggeris hendaklah diguna pakai.

1. (a) Describe the differences between thermodynamically reversible and irreversible processes.

Huraikan perbezaan antara proses termodinamik berbalik dan tidak berbalik.

(6 marks/*markah*)

(b) One mole of an ideal gas is compressed from 1 to 5 bar at 298 K. Calculate the work done on the gas if it undergoes

(i) a reversible compression.

(ii) an irreversible compression against a constant external pressure of 5 bar.

Satu mol gas unggul dimampatkan daripada 1 ke 5 bar pada 298 K. Hitung kerja yang dilakukan ke atas gas tersebut jika ia menjalani

(i) pemampatan berbalik.

(ii) pemampatan tak berbalik melawan tekanan luar yang tetap pada 5 bar.

(6 marks/*markah*)

(c) In an experiment to study the combustion reaction of a sample of fuel, the compound was burned in an oxygen atmosphere inside a calorimeter. The temperature rose by a few degrees and 1.10 kJ of heat was released. When a current of 1.12 A from a 11.5 V source flowed through a heater in the same calorimeter for 162 s, the temperature rose by 5.11°C.

(i) What is the heat capacity of the calorimeter?

(ii) How much was the temperature change during the combustion reaction?

Dalam satu eksperimen untuk mengkaji tindak balas pembakaran suatu sampel bahan api, sebatian itu telah dibakar dalam atmosfera oksigen di dalam sebuah kalorimeter. Suhu meningkat sebanyak beberapa darjah dan 1.10 kJ haba telah dibebaskan. Apabila arus sebanyak 1.12 A daripada sumber 11.5 V mengalir melalui pemanas di dalam kalorimeter yang sama selama 162 s, suhu meningkat sebanyak 5.11 ℃.

(i) Apakah muatan haba kalorimeter itu?

(ii) Berapakah perubahan suhu semasa tindak balas pembakaran berlaku?

(8 marks/*markah*)

2. (a) Two moles of an ideal gas is subjected to two successive changes in state as follows:

(i) From 25.0°C and 100.0 kPa, the gas is expanded isothermally against a constant pressure of 20.0 kPa to twice its initial volume;

(ii) At the end of process (i), the gas is cooled at constant volume from 25.0°C to –25.0°C.

Calculate heat, q, work, w, change in internal energy, ΔU and enthalpy change, ΔH, for each of the stages and for the whole process.
Given: $C_{V,m} = 3/2\ R$.

Dua mol gas unggul dikenakan dua perubahan keadaan yang berturutan seperti berikut:

(i) Dari 25.0℃ dan 100.0 kPa, gas itu telah dikembangkan secara isoterma melawan tekanan tetap 20.0 kPa kepada dua kali ganda isipadu awalnya;

(ii) Pada akhir proses (i), gas itu disejukkan pada isipadu tetap dari 25.0℃ kepada –25.0℃.

Kirakan haba, q, kerja, w, perubahan tenaga dalaman, ΔU dan perubahan entalpi, ΔH, bagi setiap peringkat dan bagi keseluruhan proses.
Diberi: $C_{V,m} = 3/2\ R$.

(16 marks/*markah*)

(b) The volume of a gas starts at 5.0 L at a temperature of 400 K and a pressure of 1.12 bar. If the change in entropy, ΔS, was 0.787 J K^{-1} mol^{-1}, what was the final volume of the gas?

Isipadu suatu gas bermula pada 5.0 L pada suhu 400 K dan tekanan pada 1.12 bar. Jika perubahan entropi, ΔS, adalah 0.787 J K^{-1} mol^{-1}, apakah isipadu akhir gas tersebut?

(4 marks/*markah*)

3. (a) What do you understand by the term **thermodynamic cycle**? Name two common devices that make use of thermodynamic cycles and explain briefly how the system functions.

*Apakah yang anda faham dengan istilah **kitaran termodinamik**? Namakan dua peranti lazim yang menggunakan kitaran termodinamik dan terangkan secara ringkas bagaimana sistem ini berfungsi.*

(5 marks/*markah*)

(b) An ideal gas, initially at V = 10.0 L, P = 1.0 bar and T = 300 K, is heated at constant volume until P = 10.0 bar. It then undergoes a reversible isothermal expansion until P = 1.0 bar. It is finally restored to its original state by the removal of heat at constant pressure.

(i) Illustrate the cyclic process in a P-V diagram.

(ii) Using the diagram, show calculations to prove that the net change of internal energy, $\Sigma\Delta U$, is equal to zero but conversely net work, Σw, is not zero.

Suatu gas unggul, pada awalnya berada pada V = 10.0 L, P = 1.0 bar dan T = 300 K, telah dipanaskan pada isipadu tetap sehingga P = 10.0 bar. Kemudian ia menjalani pengembangan isoterma berbalik sehingga P = 1.0 bar. Ia akhirnya dikembalikan kepada keadaan asalnya dengan penyingkiran haba pada tekanan tetap.

(i) Ilustrasikan proses kitaran tersebut dalam gambarajah P-V.

(ii) Dengan menggunakan gambar rajah tersebut, tunjukkan pengiraan bagi membuktikan bahawa perubahan tenaga dalaman bersih, ΣΔU, adalah bersamaan dengan sifar tetapi sebaliknya kerja bersih, Σw, bukan sifar.

(15 marks/*markah*)

4. (a) For a reversible adiabatic expansion, the following relationships are true:

$$PV^{\gamma} = \text{constant} \quad \text{and} \quad TV^{\gamma-1} = \text{constant}$$

Write an expression for T_2/T_1 in terms of P_1 and P_2, where subscripts 1 and 2 refer to the initial and final states, respectively. Then prove that the equation for work for this process is

$$w = C_V T_1 \left[\left(\frac{P_2}{P_1} \right)^{\gamma - 1/\gamma} - 1 \right]$$

Bagi pengembangan adiabatik berbalik, hubungan berikut adalah benar:

$$PV^{\gamma} = pemalar \quad dan \quad TV^{\gamma-1} = pemalar$$

Tuliskan ungkapan bagi T_2/T_1 dalam sebutan P_1 dan P_2, dimana subskrip 1 dan 2 masing-masing merujuk kepada keadaan awal dan akhir. Kemudian buktikan bahawa persamaan kerja bagi proses ini adalah:

$$w = C_V T_1 \left[\left(\frac{P_2}{P_1} \right)^{\gamma-1/\gamma} - 1 \right]$$

(5 marks/*markah*)

(b) Initially, the volume and pressure of 0.1 mol of methane gas are 2.90 L and 1 atm, respectively. The gas is allowed to expand adiabatically and reversibly to a pressure of 0.1 atm. Assume that the gas behaves ideally and the value of C_p/C_v is 1.31.

(i) What are the initial and final temperatures of the gas?

(ii) Calculate q, w, ΔU and ΔH in joule.

(iii) Could the process be carried out isothermally? Give your reason.

(iv) Suggest an alternative path to attain the same final state. Sketch both paths in a P-V diagram.

Pada awalnya, isipadu dan tekanan bagi 0.1 mol gas metana masing-masing adalah 2.90 L dan 1 atm. Gas itu dibiarkan mengembang secara adiabatik dan berbalik ke tekanan 0.1 atm. Andaikan bahawa gas ini berkelakuan unggul dan nilai C_p/C_v ialah 1.31.

(i) Apakah suhu awal dan akhir gas tersebut?

(ii) Hitung q, w, ΔU dan ΔH dalam joule.

(iii) Bolehkah proses ini dijalankan secara isoterma? Berikan alasan anda.

(iv) Cadangkan suatu laluan alternatif untuk mencapai keadaan akhir yang sama. Lakarkan kedua-dua laluan tersebut dalam gambar rajah P-V.

(15 marks/*markah*)

5. (a) State the Second Law of Thermodynamics.

Nyatakan Hukum Termodinamik Kedua.

(2 marks/*markah*)

(b) What is entropy, S? How is the change in entropy of the universe determines the spontaneity of a reaction?

Apakah entropi, S? Bagaimanakah perubahan entropi alam menentukan kespontanan sesuatu tindak balas?

(5 marks/*markah*)

(c) Determine the change in Gibbs Energy, ΔG_{rxn}, at 25°C for the following chemical reaction using the data given in **TABLE 1**. Assume standard conditions.

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

TABLE 1

	$H_2(g)$	$O_2(g)$	$H_2O(l)$
ΔH_f/ kJ mol^{-1}	0	0	–285.83
S /J mol^{-1} K^{-1}	130.68	205.14	69.91

Is the reaction spontaneous? Give your reason.

Tentukan perubahan Tenaga Gibbs, ΔG_{tbs}, pada suhu 25°C *bagi tindak balas kimia berikut menggunakan data yang diberi dalam **JADUAL 1**. Anggapkan keadaan piawai.*

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(c)$$

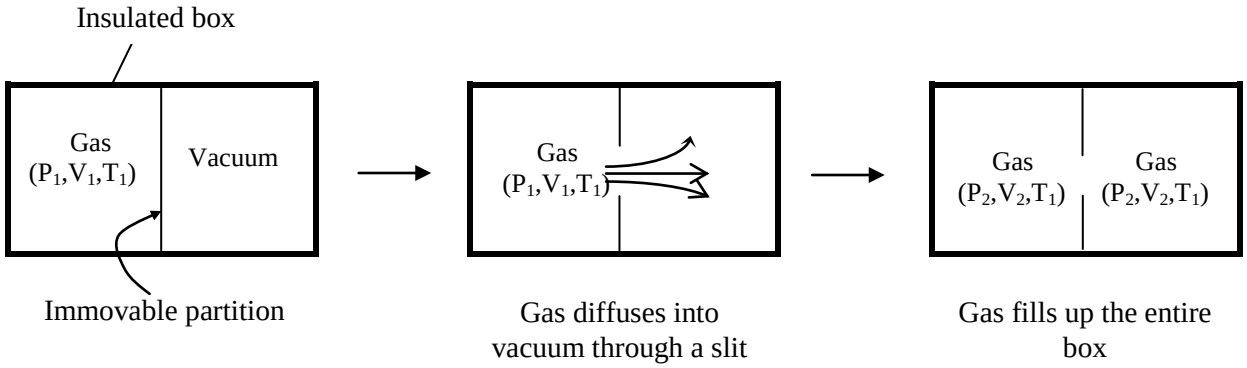
JADUAL 1

	$H_2(g)$	*$O_2(g)$*	*$H_2O(c)$*
ΔH_f / kJ mol^{-1}	*0*	*0*	*–285.83*
S /J mol^{-1} K^{-1}	*130.68*	*205.14*	*69.91*

Adakah tindak balas ini spontan? Berikan alasan anda.

(8 marks/*markah*)

(d) Study the following diagram:

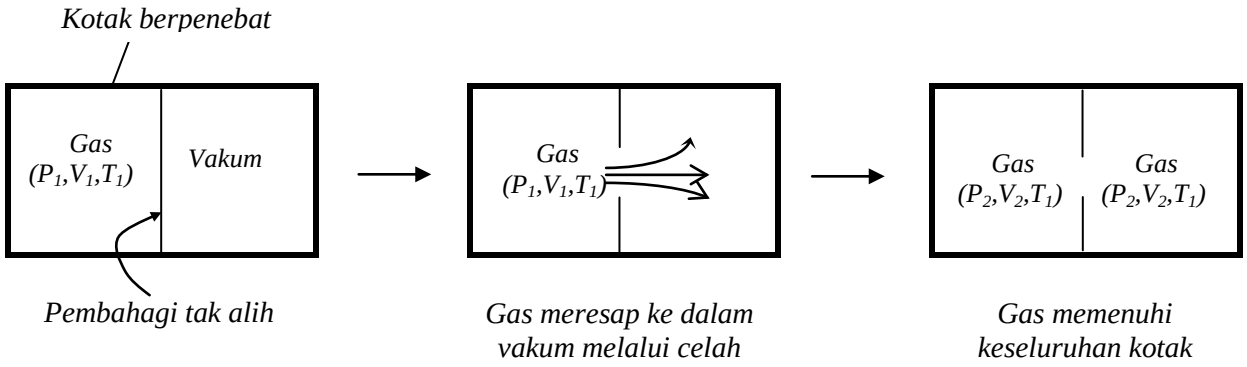


(i) What kind of thermodynamic system is the box?

(ii) Identify the thermodynamic process depicted in the diagram.

(iii) How is *w*, *q*, ΔU and ΔH change during the expansion of the gas?

Kaji gambar rajah berikut:



(i) Apakah jenis sistem termodinamik bagi kotak ini?

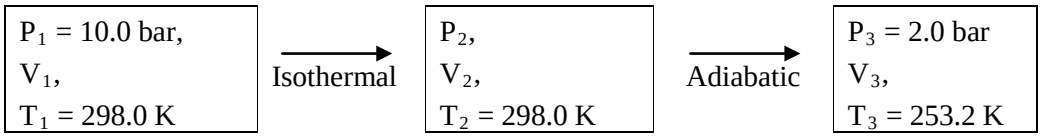
(ii) Kenalpasti proses termodinamik yang ditunjukkan dalam gambar rajah.

(iii) Bagaimanakah w, q, ΔU dan ΔH berubah semasa pengembangan gas?

(5 marks/*markah*)

6. (a) One mole of an ideal gas, initially at 10.0 bar and 298.0 K, undergoes a reversible isothermal expansion followed by a reversible adiabatic expansion. At the final state, the pressure of the gas is 2.0 bar and its temperature falls to 253.2 K.

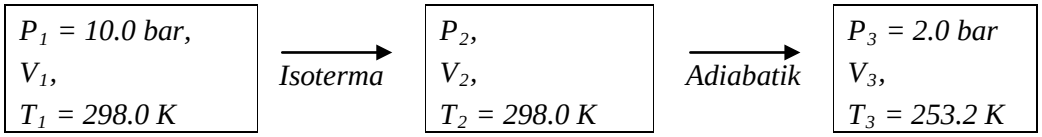
The transition is summarised in the following scheme:



Find V_1, P_2 and V_2. Assume that $C_V = 3/2\ R$.

Satu mol gas unggul, pada awalnya berada pada 10.0 bar dan 298.0 K, mengalami pengembangan isoterma berbalik diikuti dengan pengembangan adiabatik berbalik. Pada keadaan akhir, tekanan gas adalah 2.0 bar dan suhu gas menurun kepada 253.2 K.

Peralihan itu dirumuskan dalam skema berikut:



Cari V_1, P_2 dan V_2. Anggapkan bahawa $C_V = 3/2\ R$.

(10 marks/*markah*)

(b) One mole of an ideal gas at T_1 = 300 K, P_1 = 2.4618 atm and V_1 = 10 L is isothermally expanded to V_2 = 20 L against a constant external pressure of 1.2309 atm.
Calculate:

(i) ΔU, w and q for the process.

(ii) ΔS for the gas and for the surrounding.

(iii) The total entropy change for the universe. What can you conclude about the process?

Satu mol gas unggul pada T_1 = 300 K, P_1 = 2.4618 atm dan V_1 = 10 L dikembangkan secara isoterma kepada V_2 = 20 L melawan tekanan luar yang tetap pada 1.2309 atm.
Hitung:

(i) *ΔU, w dan q bagi proses ini.*

(ii) *ΔS bagi gas dan bagi sekitaran.*

(iii) *Jumlah perubahan entropi bagi alam semesta. Apakah yang dapat anda rumuskan mengenai proses ini?*

(10 marks/*markah*)

Gas Constant, R in various units

$R = 8.314\ J\ K^{-1}mol^{-1}$
$R = 8.314\ Pa\ m^3\ K^{-1}mol^{-1}$
$R = 8.314 \times 10^{-2}\ L\ bar\ K^{-1}\ mol^{-1}$

Unit of Pressure and Conversion Factors

Unit of Pressure	Symbol	Numerical Value
Pascal	Pa	$1\ Nm^{-2} = 1\ kgm^{-1}s^{-2}$
Atmosphere	atm	1 atm = 101325 Pa
Bar	Bar	$1\ bar = 10^5$ Pa
Torr or mm Hg	Torr	1 Torr = 101325/760 = 133.32 Pa

Types of Work

Types of Work	Variables	Equation for Work	Conventional Units
Volume Expansion	Pressure (P), Volume (V)	$w = -\int P_{external} dV$	Pam3 = J
Stretching	Tension (γ), length (l)	$w = -\int \gamma dl$	Nm = J

$GPa = 10^9$ Pa

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