

Assigned problems for Lecture 6 are listed below. The questions occur in the following editions of “Physical Chemistry” by P.W. Atkins:

10th edition	9th edition	8th edition
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Note: The letter “P” in front of a number indicates that the question is in the “Problem” category as opposed to the “Exercise” category in Atkins’ books. **Updates are highlighted in yellow.**

Set 1

Question 6.01

n/a	2.1	2.1
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These are problems from the 8th and 9th, but discontinued in the 10th Ed.

2.1, (8th, 9th Eds.) (a) Calculate the work needed for a 65 kg person to climb through 4.0 m on the surface of (a) the Earth and (b) the Moon ($g = 1.60 \text{ m s}^{-2}$).

2.1, (8th, 9th Eds.) (b) Calculate the work needed for a bird of mass 120 g to fly to a height of 50 m from the surface of the Earth.

Question 6.02

2A.3	2.2	2.2
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Slight variation in 10th edition questions - just the values are different, no change in how the exercise is solved.

2.2(a) A chemical reaction takes place in a container of cross-sectional area 100 cm^2 . As a result of the reaction, a piston is pushed out through 10 cm against an external pressure of 1.0 atm. Calculate the work done by the system

2.2(b) A chemical reaction takes place in a container of cross-sectional area 50.0 cm^2 . As a result of the reaction, a piston is pushed out through 15 cm against an external pressure of 121 kPa. Calculate the work done by the system.

2A.3(a) A chemical reaction takes place in a container of cross-sectional area 50 cm^2 . As a result of the reaction, a piston is pushed out through 15 cm against an external pressure of 1.0 atm. Calculate the work done by the system.

2A.3(b) A chemical reaction takes place in a container of cross-sectional area 75.0 cm^2 . As a result of the reaction, a piston is pushed out through 25.0 cm against an external pressure of 150 kPa. Calculate the work done by the system.

Question 6.03

2A.5	2.4	2.4
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2A.5(a) A sample consisting of 1.00 mol of perfect gas atoms, for which $C_{V,m} = \frac{3}{2}R$, initially at $p_1 = 1.00$ atm and $T_1 = 300$ K, is heated reversibly to 400 K at constant volume. Calculate the final pressure, ΔU , q , and w .

2A.5(b) A sample consisting of 2.00 mol of perfect gas molecules, for which $C_{V,m} = \frac{5}{2}R$, initially at $p_1 = 111$ kPa and $T_1 = 277$ K, is heated reversibly to 356 K at constant volume. Calculate the final pressure, ΔU , q , and w .

Question 6.04

2A.6	2.5	2.5
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2A.6(a) A sample of 4.50 g of methane occupies 12.7 dm³ at 310 K. (i) Calculate the work done when the gas expands isothermally against a constant external pressure of 200 Torr until its volume has increased by 3.3 dm³. (ii) Calculate the work that would be done if the same expansion occurred reversibly.

2A.6(b) A sample of argon of mass 6.56 g occupies 18.5 dm³ at 305 K. (i) Calculate the work done when the gas expands isothermally against a constant external pressure of 7.7 kPa until its volume has increased by 2.5 dm³. (ii) Calculate the work that would be done if the same expansion occurred reversibly.

Question 6.05

n/a	n/a	n/a
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These is a problem from the 7th edition (Ex. 2.10a, 7th Ed.) that was discontinued from later editions.

Ex. 2.10a, 7th Ed. In the isothermal reversible compression of 52.0 mmol of a perfect gas at 260 K, the volume of the gas is reduced to one-third of its original value. Calculate the w for this process.

Answer: (Ex. 2.10a, 7th Ed.), $w = +123$ J (use $w = -nRT \ln (V_f/V_i)$), see below for full solution.

Question 6.06

n/a	2.7	2.7
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Yet another good problem which seems to be missing.

2.7 (8th, 9th Eds.) (a) A strip of magnesium of mass 15 g is placed in a beaker of dilute hydrochloric acid. Calculate the work done by the system as a result of the reaction. The atmospheric pressure is 1.0 atm and the temperature 25°C.

2.7 (8th, 9th Eds.) (b) A piece of zinc of mass 5.0 g is placed in a beaker of dilute hydrochloric

acid. Calculate the work done by the system as a result of the reaction. The atmospheric pressure is 1.1 atm and the temperature 23°C.

Solution 6.01

n/a	2.1	2.1
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E2.1(a) The physical definition of work is $dw = -F dz$ [2.5].

In a gravitational field the force is the weight of the object, which is $F = mg$.

If g is constant over the distance the mass moves, dw may be integrated to give the total work

$$w = -\int_{z_i}^{z_f} F dz = -\int_{z_i}^{z_f} mg dz = -mg(z_f - z_i) = -mgh, \quad \text{where } h = (z_f - z_i)$$

On earth: $w = -(65 \text{ kg}) \times (9.81 \text{ m s}^{-2}) \times (4.0 \text{ m}) = -2.6 \times 10^3 \text{ J} = \boxed{2.6 \times 10^3 \text{ J needed}}$

On the moon: $w = -(65 \text{ kg}) \times (1.60 \text{ m s}^{-2}) \times (4.0 \text{ m}) = -4.2 \times 10^2 \text{ J} = \boxed{4.2 \times 10^2 \text{ J needed}}$

E2.1(b) The physical definition of work is $dw = -F dz$ [2.4]

In a gravitational field the force is the weight of the object, which is $F = mg$

If g is constant over the distance the mass moves, dw may be intergrated to give the total work

$$w = -\int_{z_i}^{z_f} F dz = -\int_{z_i}^{z_f} mg dz = -mg(z_f - z_i) = -mgh \quad \text{where } h = (z_f - z_i)$$

$w = -(0.120 \text{ kg}) \times (9.81 \text{ m s}^{-2}) \times (50 \text{ m}) = -59 \text{ J} = \boxed{59 \text{ J needed}}$

Solution 6.05

n/a	n/a	n/a
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E2.10(a) $w = -nRT \ln \frac{V_f}{V_i}$ [2.13] $V_f = \frac{1}{3} V_i$

$$nRT = (5.20 \times 10^{-3} \text{ mol}) \times (8.314 \text{ J K}^{-1} \text{ mol}^{-1}) \times (260 \text{ K}) = 1.124 \times 10^2 \text{ J}$$

$$w = -(1.124 \times 10^2 \text{ J}) \times \ln \frac{1}{3} = \boxed{+123 \text{ J}}$$

Solution 6.06

n/a	2.7	2.7
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E2.7(a)

The chemical reaction that occurs is



Work is done against the atmosphere by the expansion of the hydrogen gas produced in the reaction.

$$w = -p_{\text{ex}} \Delta V \quad [2.10]$$

$$V_i = 0, \quad V_f = \frac{nRT}{p_f}, \quad p_f = p_{\text{ex}} \quad w = -p_{\text{ex}}(V_f - V_i) = (-p_{\text{ex}}) \times \frac{nRT}{p_{\text{ex}}} = -nRT$$

$$n = \frac{15 \text{ g}}{24.31 \text{ g mol}^{-1}} = 0.617 \text{ mol}, \quad RT = 2.479 \text{ kJ mol}^{-1}$$

Hence, $w = (-0.617 \text{ mol}) \times (2.479 \text{ kJ mol}^{-1}) = \boxed{-1.5 \text{ kJ}}$

E2.7(b) The reaction is

so it liberates 1 mol of $\text{H}_2\text{(g)}$ for every 1 mol Zn used. Work at constant pressure is

$$w = -p_{\text{ex}} \Delta V = -pV_{\text{gas}} = -nRT$$

$$= -\left(\frac{5.0 \text{ g}}{65.4 \text{ g mol}^{-1}}\right) \times (8.3145 \text{ J K}^{-1} \text{ mol}^{-1}) \times (23 + 273) \text{ K} = \boxed{-188 \text{ J}}$$