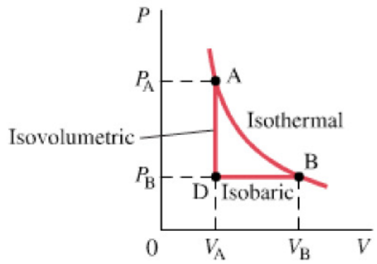


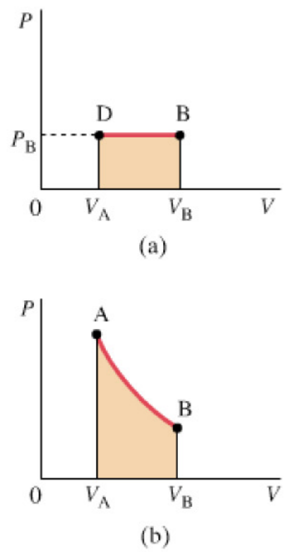
FIGURE 15–6 *PV* diagram for different processes (see the text), where the system changes from A to B.

Figure 15–6 shows the isotherm AB we saw in Fig. 15–2 as well as another possible process represented by the path ADB. In going from A to D, the gas does no work since the volume does not change. But in going from D to B, the gas does work equal to $P_B(V_B - V_A)$, and this is the total work done in the process ADB.

Work = area under PV curve

If the pressure varies during a process, such as for the isothermal process AB in Fig. 15–2, Eq. 15–3 cannot be used directly to determine the work. A rough estimate can be obtained, however, by using an "average" value for P in Eq. 15–3. More accurately, the work done is equal to the area under the *PV* curve. This is obvious when the pressure is constant: as Fig. 15–7a shows, the shaded area is just $P_B(V_B - V_A)$, and this is the work done. Similarly, the work done during an isothermal process is equal to the shaded area shown in Fig. 15–7b. The calculation of work done in this case can be carried out using calculus, or by estimating the area on graph paper.

FIGURE 15–7 Work done by a gas is equal to the area under the *PV* curve.



CONCEPTUAL EXAMPLE 15–3 **Work in isothermal and adiabatic processes.** In Fig. 15–3 we saw the *PV* diagrams for a gas expanding in two ways, isothermally and adiabatically. The initial volume V_A was the same in each case, and the final volumes were the same $(V_B = V_C)$. In which process was more work done by the gas?

RESPONSE Our system is the gas. More work was done by the gas in the isothermal process, which we can see in two simple ways by looking at Fig. 15–3. First, the "average" pressure was higher during the isothermal process AB, so $W = P_{av}\,\Delta V$ was greater (ΔV is the same for both processes). Second, we can look at the area under each curve: the area under curve AB, which represents the work done, was greater (since curve AB is higher) than that under AC.

EXERCISE B Is the work done by the gas in process ADB of Fig. 15–6 greater than, less than, or equal to the work done in the isothermal process AB?

CONCEPTUAL EXAMPLE 15–4 **Simple adiabatic process.** Here is an example of an adiabatic process that you can do with just a rubber band. Hold a thin rubber band loosely with two hands and gauge its temperature with your lips. Stretch the rubber band suddenly and again touch it lightly to your lips. You should notice an increase in temperature. Explain clearly why the temperature increases.

RESPONSE Stretching the rubber band *suddenly* makes the process adiabatic because there is no time for heat to enter or leave the system (the rubber band), so $Q = 0$. You do work on the system, representing an energy input, so W is negative in Eq. 15–1 $(\Delta U = Q - W)$. Hence ΔU must be positive. An increase in internal energy corresponds to an increase in temperature (for an ideal gas it is given by Eq. 14–1).

Table 15–1 gives a brief summary of the processes we have discussed.

TABLE 15–1 Simple Thermodynamic Processes and the First Law

Process	What is constant:	The first law predicts:
Isothermal	T = constant	$\Delta T = 0$ makes $\Delta U = 0$, so $Q = W$
Isobaric	P = constant	$Q = \Delta U + W = \Delta U + P\,\Delta V$
Isovolumetric	V = constant	$\Delta V = 0$ makes $W = 0$, so $Q = \Delta U$
Adiabatic	$Q = 0$	$\Delta U = -W$